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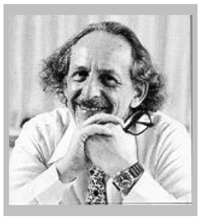

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'*Of Nobel Class*': Part 2. Forecasting Nobel Prizes Using Citation Data and the Odds Against It

Number 35 August 31, 1992

The reprint that follows this introduction is the second part of an article[1] published in *Theoretical Medicine* by myself and Alfred Welljams-Dorof, my scientific assistant at the Institute for Scientific Information® (ISI®). The paper addresses an interesting point that has been explored in previous *Current Comments®* essays: Do quantitative rankings of highly cited authors confirm—and even anticipate—Nobel prize awards?

The first part of the reprinted paper[2] presented an overview of six previous ISI studies of most-cited authors. It discussed the number of authors who had already won the prize at the time each essay was originally published as well as the number who later went on to become Nobel laureates. These undifferentiated rankings were shown to have effectively identified a relatively small set of authors "of Nobel class," including actual Nobelists.

In the second part reprinted here, the possibility of *forecasting* Nobel prize winners using citation data is discussed. We present a list of 100 authors who were most cited from 1981 through 1990 for papers they published during this period. Eight Nobelists appear on the list, and it will be interesting to see how many more become laureates in future years.

It is remarkable that a simple, quantitative, and objective algorithm can indeed corroborate and anticipate the complex, qualitative, and subjective selection process of the Nobel prize committee. This is even more noteworthy considering the odds against successfully forecasting the awards with citation data, which also are reviewed in Part 2. Several factors might limit the effectiveness of undifferentiated citation rankings to anticipate Nobel awards—for example, the tendency for life science fields to dominate, the purported overrepresentation of methods papers and authors, the "obliteration by incorporation" phenomenon, etc.[3,4]

In the third part of this essay, the editor of *Theoretical Medicine* will provide a condensed version of his introduction to the special issue on the Nobel prize. The table of contents for the issue appears on the following page.

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THEORETICAL MEDICINE
Volume 13 No. 2 June 1992, 138 p.
DISCOVERY, THEORY CHANGE, AND THE NOBEL PRIZE:
ON THE MECHANISMS OF SCIENTIFIC EVOLUTION
Issue Editor: B.I.B. Lindahl

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OF NOBEL CLASS: A CITATION PERSPECTIVE ON HIGH IMPACT RESEARCH AUTHORS (Part 2)

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3. A FORECAST FOR THE 1990S

Despite the possible methodological limitations, to be discussed in the next section, lists of the highest impact authors in a given time period are still rather effective in identifying past, present, and future Nobelists. As an outlook on laureates-to-be of the 1990s, we have identified the 100 most-cited authors of articles published and cited in 1981-1990. They are listed in Table III.

Eight Nobelists through 1990 are included, indicated by asterisks. While this article was in press, the 1991 Nobel prizes were announced. The new laureates for medicine or physiology are Erwin Neher of the Max Planck Institute for Biophysical Chemistry, Göttingen, and Bert Sakmann, Max Planck Institute for Medical Research, Heidelberg. Although neither appears in Table III, both *are* among the 300 most-cited scientists of the 1980s with over 5,800 citations each to their 1980s papers. The 1991 Nobel prize winner in chemistry is Richard Ernst of the Eidgenossische Technische Hochschule, Zürich. With more than 6,200 citations to his 1980s publications, Ernst also ranks among the 300 most-cited scientists of the decade. Pierre-Gilles de Gennes, College de France, Paris, was awarded the 1991 Nobel prize for physics. His 1980s papers were cited over 2,100

Table III
Most-cited authors of the 1980s, ranked by citations to papers indexed in the 1981-1990 *Science Citation Index* (*SCI*).

Author	Field[1]	1981-1990 Citations	1981-1990 Papers
Gallo RC	Virology	36,789	591
Schlossman SF	Immunology	21,682	348
Nishizuka Y	Cell Biology	20,143	181
Hood LE	Molecular Biology	18,288	324
Messing J	Molecular Biology	18,229	35
Fauci AS	Immunology	17,756	563
Bloom SR	Gastroenterology	16,543	1,468
Vale W	Neuroendocrinology	16,422	348
Dinarello CA	Immunology	16,143	482
Berridge MJ	Cell Biology	16,004	93
Rosenberg SA	Surgery/Oncology	15,922	430
Rivier J	Endocrinology	15,893	320
Seeburg PH	Neurobiology	14,454	124
Irvine RF	Cell Biology	14,431	108
Chambon P	Molecular Biology	14,190	246
Reinherz EL	Immunology	14,067	220
Wong-Staal F	Virology	13,910	254
*Baltimore D	Virology	13,847	222
*Goldstein JL	Genetics	13,120	202
*Brown MS	Biochemistry	13,031	171
Franke WW	Cell Biology	12,930	280
Hokfelt T	Neuropharmacology	12,881	381
Strominger JL	Virology	12,817	253
Ullrich A	Biochemistry	12,670	199
*Bishop JM	Virology	12,427	162
*Thomas ED	Oncology	12,306	412
Snyder SH	Pharmacology	12,302	308
Witten E	Physics	12,105	96
Sporn MB	Biochemistry	11,657	182
Lefkowitz RJ	Pharmacology	11,619	320
Weber K	Biochemistry	11,607	270
Polak JM	Histology	11,583	924
Springer TA	Cell Biology	11,234	199
Maniatis T	Molecular Biology	11,167	81
Evans RM	Molecular Biology	10,980	191
Weinberg RA	Molecular Biology	10,831	138
Lundberg JM	Physiology	10,810	304
Waldmann TA	Immunology	10,658	195
Leder P	Molecular Biology	10,620	115
Cerami A	Biochemistry	10,593	263
Ruoslahti E	Molecular Biology	10,468	180
Hunter T	Molecular Biology	10,465	216
Marrack P	Immunology	10,377	157
Tjian R	Molecular Biology	10,334	109
Pastan I	Biochemistry	10,319	337
Sarngadharan MG	Virology	10,181	118
Vogelstein B	Oncology	10,128	99
Sharp PA	Molecular Biology	10,099	167
Storb R	Immunology	9,995	439
Collen D	Hematology	9,985	381
Gossard AC	Physics	9,954	304
Vieira J	Molecular Biology	9,921	21
Herberman RB	Oncology	9,907	345
Austen KF	Immunology	9,846	366
Tsien RY	Physiology	9,742	94

Table III (cont.)

Author	Field[1]	1981-1990 Citations	1981-1990 Papers
Ling N	Neuroendocrinology	9,604	244
Gilman AG	Pharmacology	9,590	72
Goeddel DV	Neuroscience	9,552	93
Montagnier L	Virology	9,494	189
Feinberg AP	Genetics	9,375	21
Tatemoto K	Neurochemistry	9,272	195
Greengard P	Cell Biology	9,246	264
Koprowski H	Microbiology	9,231	332
Goldstein G	Immunology	9,086	183
Aaronson SA	Oncology	9,039	178
Roberts AB	Molecular Biology	9,024	145
Popovic M	Virology	8,992	181
Rosenfeld MG	Molecular Biology	8,959	135
Takai Y	Biochemistry	8,927	136
Fiers W	Molecular Biology	8,863	256
Paul WE	Immunology	8,862	177
Van Houtte PM	Cardiology	8,837	475
Gillis S	Immunology	8,723	204
*Varmus HE	Virology	8,680	120
Sugimura T	Oncology	8,533	427
Greene WC	Oncology	8,495	172
Starzl TE	Surgery/Transplants	8,447	640
Caron MG	Biochemistry	8,428	247
Braunwald E	Cardiology	8,427	290
Matsuo H	Biochemistry	8,402	295
Numa S	Molecular Biology	8,341	112
Oppenheim JJ	Immunology	8,300	200
Crystal RG	Medicine	8,293	315
Verma IM	Molecular Biology	8,254	112
Ui M	Molecular Biology	8,211	163
Croce CM	Genetics	8,208	218
Genest J	Biochemistry	8,162	353
Cantin M	Medicine	8,124	382
Doolittle RF	Biochemistry	8,046	79
Timpl R	Biochemistry	7,961	253
Wuthrich K	Molecular Biology	7,897	197
Minna JD	Oncology	7,897	165
Hsu SM	Molecular Biology	7,847	123
*Corey EJ	Chemistry	7,833	307
Waterfield MD	Biochemistry	7,803	79
Rutter WJ	Endocrinology	7,802	159
Swanson LW	Neuroscience	7,723	171
Schlessinger J	Molecular Biology	7,691	170
Goldstein M	Neurochemistry	7,611	303
*Tonegawa	Immunogenetics	7,571	84

*Nobel laureate

times, which places him among the 1,500 most-cited researchers of the decade. No doubt, he would rank among the top 100 if we considered only the most-cited *physicists* of the 1980s, for reasons discussed in the following section.

Data are available to test whether productivity, author impact, and paper impact are possible 'markers' of laureates-to-be. These rankings are in preparation and will be published when completed. They may prove to be more or less effective in targeting laureates-to-be, especially when combined with other independent indicators, such as Lasker Award winners, academy elections, etc.

This was done in a forecast of Nobel winners in medicine for 1989 that appeared in *The Scientist*.[23] Out of a list of about 200 most-cited authors in the 1973-84 *Science Citation Index*® (*SCI*®), the field of most-likely candidates was narrowed down to just 20 names by also considering who had already won the Albert Lasker Basic Medical Research Award, the Gairdner International Award, and other 'predictor prizes'. The 1989 winners, J.M. Bishop and H.E. Varmus, were on the list.

4. DISCUSSION

4.1. Nobelists in Smaller Specialties

All the lists we've reviewed are undifferentiated rankings of the most-cited authors in a given time period. The most-cited authors in larger fields achieve higher citation rates. So molecular biology, genetics, biochemistry, and other life sciences tend to dominate, and fewer authors in physics and chemistry are represented. Despite this limitation, the method still effectively anticipates future Nobel awards.

However, the Nobel Committee sometimes selects relatively small specialties for recognition. Authors in these areas may not show up in listings for the established disciplines. But when citation data for the specialty is *disaggregated*[21], the forecasting results significantly improve.

An example is radio astronomy, recognized by 1978 Nobel awards to R.W. Wilson and A.A. Penzias. Both ranked among the top 5 authors in their field, cited in the 1961-1975 *SCI*.[18] Another example is computerized axial tomography. The 1979 Nobel was awarded to G.N. Hounsfield and A.M. Cormack. They were among the 15 authors in this specialty most-cited in the 1961-79 *SCI*.[18] In both instances, a small set of authors ranked by citation frequency included, that is, anticipated, the Nobel awards.

4.2. Nobelists in Economics and Literature

The Nobel prize for economics, first awarded in 1969, provides another opportunity for citation comparisons. In 1990, we listed the top 50 economists most-cited as *primary* authors of both articles *and* books in the 1966-86 *Social Sciences Citation Index*® (*SSCI* ®).[24] It included seven authors who were deceased and therefore not eligible for the prize, which is restricted to living individuals.

Fifteen Nobelists were listed—an incredible 62.5% of the 24 economics awards through 1986. In addition, two laureates-to-be, R.M. Solow (1987) and R.H. Coase (1991), were listed. Of course, future prizes may still be won by those listed who are eligible.

The Nobel prize for literature abounds in controversies about personal, geographic, and philosophical biases. Still, citation rankings succeed in corroborating a significant proportion of Nobel literature awards.

For example, a list of the 100 authors most-cited in the 1977-78 *Arts & Humanities Citation Index*® (*A&HCI* ®) included 25 Nobelists.[25] Only two so far are laureates-to-be—Gabriel Garcia Marquez (1982) and Octavio Paz (1990). But this is 7.1% of the 28 names on the list still eligible for the award in 1990. Five authors who became Nobelists within the five years previous to the study were identified. It would seem that citation rankings can also be effective in forecasting Nobel literature prizes.

4.3. The Odds Against Forecasting Nobels with Citation Data

As stated earlier, 26 laureates-to-be in science have been identified by a quantitative and objective algorithm that ranks authors by total citations.[12-17] One-third of all Nobel

Table I
Summary information on most-cited author studies based on *Science Citation Index* (*SCI*) data.

	1967[a]	1972[b]	1961-72[b]	1961-75[c]	1961-76[d]	1965-78[e]
PRE Nobel						
Authors	8	5	5	13	15	26
Citations	6,274	4,859	40,376	94,586	99,468	120,248
Impact	784	972	8075	7276	6631	4625
POST Nobel						
Authors	6	7	13	38	22	35
Citations	5,107	6,966	100,923	279,472	146,652	174,252
Impact	851	995	7763	7355	6666	4979
ALL Nobel						
Authors	14	12	18	51	37	61
Citations	11,381	11,825	141,299	374,058	246,120	294,500
Impact	813	985	7850	7334	6652	4828
NON Nobel						
Authors	36	38	32	198	263	939
Citations	29,287	34,091	259,613	1,194,775	1,402,326	3,515,504
Impact	813	897	8113	6034	5332	3744
*Authors	35	37	31	197		
*Citations	26,366	28,166	224,415	1,136,471	NA	NA
*Impact	753	761	7239	5769		
Total						
Authors	50	50	50	249	300	1,000
Citations	40,668	45,916	400,912	1,568,833	1,648,446	3,810,004

[a] Based on [2]
[b] Based on [3]
[c] Based on [4-6]
[d] Based on [7-11]
[e] Based on [12-17]
*Excluding citations to O.H. Lowry.

prizes in medicine, chemistry, and physics from 1979 to 1990 have been anticipated by the list of most-cited authors in the 1965-78 *SCI*. Considering all the possible factors that can limit an undifferentiated citation ranking, it is remarkable that such a large number of laureates-to-be can consistently be identified.

We have already discussed one such limitation, the trend for life science fields to dominate the rankings. Another is the purported dominance of methods papers and authors. ISI's lists of most-cited authors and articles[26-47] would provide a good sample to test this anecdotal assumption, but it remains to be done. Of course, high impact methods—and their authors—will appear and can 'skew' the results.

4.3.1. The Lowry Phenomenon

A classic example is Oliver Lowry, whose 1951 methods paper has been extraordinarily cited—more than 205,000 times through 1990.[48] If the most-cited author data are adjusted (censored) for the 'Lowry factor', the average impact of non-Nobelists drops about 5% to 18% across the four applicable lists. The summary data in Table I shows this.

However, Lowry is a statistical anomaly, an extreme far beyond the normal citation range of methods papers or authors. No doubt, other authors of high impact methods papers will appear on undifferentiated lists. But the fact that so many present and future Nobelists also appear would argue that theoretical authors rank high as well. Their individual paper impact may be lower, but the cumulative impact resulting from their higher than average productivity puts them in the upper echelon of cited authors.

It is interesting that researchers tend to hold theoretical advances in greater esteem than methodological contributions. But new methods, techniques, and instruments play an important and even critical role in scientific research. They frequently increase the efficiency, speed, and sensitivity of laboratory and clinical studies. They also often enable researchers to conduct experiments that otherwise would have been extremely difficult if not impossible. For these reasons, methodological contributions deserve appreciation and recognition on a par with theoretical advances. Indeed, the Nobel prizes have recognized exceptional methodological breakthroughs—for example, the 1991 chemistry award to R. Ernst for his development of nuclear magnetic resonance spectroscopy; the 1986 physics award to E. Ruska for devising the electron microscope, and to G. Binnig and H. Rohrer for designing the scanning tunneling microscope; the 1979 physiology or medicine award to A.M. Cormack and G.N. Hounsfield for inventing the computerized axial tomography scanner, and so on.

4.3.2. The Obliteration Phenomenon

It is well established that certain papers reporting landmark findings are paradoxically *under*-cited or even *un*cited. They are rapidly incorporated into the canonical knowledge of a field, and references are no longer *explicitly* cited in bibliographies or footnotes. This is known as 'obliteration by incorporation'.[49,50]

A good example is the 1953 Watson and Crick letter to *Nature* describing the double-helical structure of DNA.[51] It was cited 'only' about 1,400 times through 1990. Its citation is now virtually 'totemic'—it is cited more for its place in science history than for its content.

4.3.3. Premature and Post-Mature Discovery

Certain ideas or methods seem to have been overlooked by contemporary scientists and then 'rediscovered' many years later. These discoveries may have been *pre*mature—literally ahead of the prevailing wisdom of their times, conceptually or practically.[52] Or they may be *post*-mature—advances that, in retrospect, should have been made earlier.[53]

Illustrative cases have been rare and anecdotal. Citation data suggest the phenomenon is perhaps more common than usually thought. In a still-continuing series on the most-cited papers of 1945-1988, annual citation distributions were used to identify possible 'sleepers' or 'late bloomers'.[54-56] Whether or not they are genuine cases of pre- or post-mature discovery depends on the informed opinion of experts close to the subject.

5. CONCLUSION

The data reviewed here indicate that author citation rankings are an effective method for identifying both past and present Nobelists as well as laureates-to-be. It is difficult to say what is really more remarkable. That a simple, quantitative, objective algorithm can corroborate and anticipate a complex, qualitative, subjective selection process? Or that a highly subjective process can consistently select authors having the highest quantitative and objective impact in medicine, chemistry, physics, economics, and literature?

As stated earlier, Nobelists are consistently highly cited while only a small percentage of most-cited authors win the prize. It would be expected that a large percentage of the latter are elected to national academies of science. But a study remains to be completed. Certainly in the former USSR and elsewhere, other factors besides scientific achievement enter the equation.

NOTES

[1] Authors' fields in Table III were self-defined in questionnaires sent to those who appeared in the 1965-1978 study of the 1,000 most-cited scientists.[12-17] For non-respondents and authors who did not appear in that study, fields were defined by the department affiliation in the addresses listed in their recent papers. When departments were not specified, fields were defined by titles of articles and journals.

[2] Citation data can be disaggregated for various specialties in several ways. The simplest method is to use *journal titles* to define specialties. This can be done by broad field categories (e.g., journals of life sciences, medicine, chemistry, physics, and so on) or by particular subdisciplines within fields (e.g. journals of genetics, immunology, electrochemistry, particle physics, and so on). Of course, this method relies on the subjective definitions of fields and specialties made by journal publishers, editors, or subject specialists. In addition, multidisciplinary journals—such as *Nature* or *Science*—defy easy categorization by field or specialty.

A more sophisticated method is to use co-citation analysis to identify discrete clusters of research specialties. The method has been described in detail in previous publications.[57, 58] Simply described, co-citation clustering involves tracking *pairs* of papers that are cited together in articles ISI indexes on an annual basis. An algorithm pairs all references cited in a particular article, and identifies other papers that co-cite the same pairs of articles. When the same pairs are co-cited with other papers by many authors, a *cluster* of research begins to form. The co-cited papers in these clusters share some common topic, subject area, or method. The cluster is automatically named by using the words and phrases that citing authors themselves provide in the titles of their articles.

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