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Current Comments

Are the 1979 Prizewinners *of Nobel Class*?

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Part of the process of scientific discovery is linguistic. It is not only necessary for scientists to observe and discover phenomena, but also to name them. Thus, the coining of new terms (neologisms) is very important to the growth of science. During a recent discussion with Columbia University Professors Robert K. Merton and Harriet Zuckerman, a new and, I believe, useful term was born.

For years historians and sociologists have been talking about scientists who are outstanding in one way or another. Usually they are recognized through prestigious awards or election to national academies. Nobel prizewinners are the most visible, and generally undisputed, members of this elite.

For every scientist and scholar who wins the Nobel prize, though, there are at least a dozen others who are *of Nobel class*. I do not have a list of all the people who have been candidates for this award but, of course, they outnumber those who have been named. Zuckerman, in her book *Scientific Elite*,[1] likens this group to the "immortals," who, though equal in stature, are not included in the French Academy's limited membership of 40. Adapting an earlier usage,[2] she refers to these individuals "...who are peers of prizewinners in every sense except that of having the award"[1] (p. 42) as occupants of the "forty-first chair." Such people can be identified as *of Nobel class*.

At the Institute for Scientific Information® (ISI®), we use citation analysis techniques to identify individual authors who have had high impact, and in the process, we may identify some who are *of Nobel class*. A scientist whose work is often referred to by others in his field certainly has had some effect on the work of his peers. However, I have repeatedly cautioned that not all deserving scientists may be recognized by being cited by their peers. Their work may be obliterated.[3] Cases of delayed recognition can occur.[4] And not all scientists with high impact may have done work worthy of recognition by awards committees.[5] Their work may have high impact in the negative sense. For example, it may be highly controversial.

Similarly, citation analysis cannot *predict* Nobel prizewinners. Certainly, we cannot duplicate the Nobel Committee's judgment. I suppose I have only myself to blame when relatively uninformed people ask to use *Science Citation Index® (SCI®)* data to predict the next group of Nobel prizewinners. This is probably because the appearance of Nobel prizewinners on so many of our lists of highly cited authors and articles attests to the relationship between citedness and other forms of scientific recognition.

The term, *of Nobel class*, makes my life a little easier. When I am asked to produce the names of likely winners, I can simply say, "Here's a list of people who may be *of Nobel class*. They have never won the prize but they have outstanding records, having published significant numbers of papers of high impact. Their work has been cited consistently, which is in many cases identified with major breakthroughs in science."

Even if there were a perfect correlation between citation ranking and peer judgment—and there isn't—we could not predict Nobel prizewinners because it is really not individual winners, as such, one is trying to predict. In this parlor game, what you are trying to do is guess which field of science or discovery or specialty the Nobel Committee will consider worthy of recognition next time around.

So even though we may compile for each and every major discipline and subspecialty a list of people who may be *of Nobel class*, there is no definitive way to determine who will win the Nobel prizes next year or the year after. But, as it turns out, our lists do anticipate most of the people who *eventually* do win Nobel prizes. The occasional anomaly is due to the selection of a scientist from a relatively small field considered to be of Nobel significance, but where the literature may be small compared to established fields like molecular biology or particle physics.

A good example is the field of radio astronomy. The 1978 Nobel prizewinners in physics, radio astronomers R.W. Wilson and A.A. Penzias, received "only" 1,400 and 1,200 citations, respectively, from 1961 to 1975. Although these are impressive citation counts, they seem less impressive when you consider that at least 1,000 authors were cited 2,000 times or more in the same period. However, there's a relatively small body of literature on radio astronomy and in this field Wilson and Penzias ranked as the second and fifth most-cited authors during the period 1961 to 1975. (See Table 1.)

Like most scientists, I read the annual announcements of the Nobel prizewinners with considerable interest. Naturally, I was pleased that several of the 1979 winners have appeared on ISI's lists of highly cited authors and articles. As a matter of fact, if they hadn't, it would have been an immediate sign that the committee had decided to make an award in a less well-known field, such as radio astronomy.

Table 1: Most-cited authors in radio astronomy*

Authors	**Total Citations 1961-75**
Low F J	1,953
Wilson R W	1,412
Zuckerman B	1,389
Berklin E E	1,286
Penzias A A	1,235
Palmer P	1,123
Gwinn W D	971
Thaddeus P	960
Solomon P M	949
Barrett A H	911
Turner B E	876
Goss W M	851
Herbig G H	710
Snyder L E	676
Wilson W J	653
Radhakrishnan V	633
Heiles C	612
Habing H J	608
Werner M W	605
Schraml J	540
Wynn-Williams C G	540
Watson W D	527
Litvak M M	523
Kleinmann D E	509
Reifenstein E C	463
Altenhoff W J	368

*Based on ISI® cluster data

1979 Prizewinners in Chemistry

The Nobel prizewinners in chemistry—Herbert C. Brown and Georg Wittig—are so well known to chemists for their work in organic synthesis that it seems unnecessary to point out they've repeatedly appeared on our lists of highly cited authors and articles. Purdue University Professor Emeritus Brown was recognized for his work with hydroboranes (mixtures of hydrogen and boron). These compounds are now used to make insecticides that control pests without the use of poisons. Hydroboranes are also used in the formulation of pharmaceuticals, such as hormones and steroids.[6] The pervasive influence of Brown's work is evidenced by the more than 21,000 citations to his work in the past 20 years. Brown appeared on the first list of highly cited authors I ever published.[7] At that time he was ranked the fourth most-cited author in 1967. In an updated report on that list, published in 1973,[8] he was the fourth most-cited author in 1972, and the third most-cited during the period 1961-1972. Of the four authors on these lists who had accumulated a greater number of citations than Brown, one, L.D. Landau, has won the 1962 Nobel prize in physics. The others, O.H. Lowry,[9] B. Chance, and J.A. Pople, are members of several honorary societies and have won numerous awards. This, plus their impressive citation records, clearly identifies them as being *of Nobel class.*

These lists were based on so-called first-author data, as was a more recent study covering 1961-75.[10] Brown is also found to be highly cited when co-authors are taken into account. As a matter of fact, Brown ranked thirteenth among the 300 most-cited authors when we included coauthors for the years 1961-1976.[11] Incidentally, one of Brown's most-cited articles, mentioned in an earlier study,[12] is a 1958 classic on "Electrophilic substituent constants."[13] This paper was also the fifth most-cited article in a group of physics and chemistry papers published in the 1950s.[14] The longevity of this paper was demonstrated when it turned up again among the chemical articles most-cited in 1972.[15] His letter to the editor of the *Journal of the American Chemical Society* concerning the chromic acid oxidation of alcohols into ketones,[16] was another of his highly cited papers.[17] However, neither of these important papers was the basis of his Nobel prize. Brown has published so extensively on the subject of hydroboranes that, not surprisingly, it is impossible to identify any specific paper as his key publication. One of his earliest papers on hydroboranes[18]—published in 1939, a year after he received his doctorate[19,20]—is still being cited. Entitled "Hydrides of boron. XI. The reaction of diborane with organic compounds containing a carbonyl group," this "first report of the application of a hydride for the reduction of organic functional groups"[20] (p. 3) has been cited 41 times during the 19 years covered by *SCI*. When we compile *SCI* data for earlier years, I'm sure this number will increase significantly. The 1955-60 *SCI* data are being compiled right now.

University of Heidelberg Professor Emeritus Wittig's award-winning work on the development of a highly specific method for the synthesis of olefins has been well cited in the chemical literature. Wittig has been cited over 7,300 times since the *SCI* was initiated in 1961. (This is remarkable since his first papers were published in the 1920s.) The Nobel prize was awarded to Wittig for his discovery that phosphorus ylides react with ketones and aldehydes to form alkenes. This technique—called the Wittig synthesis or reaction[21]—has proved to be invaluable in the synthesis of pharmaceuticals and other complex substances. It is also important for the synthesis of insect pheromones, which are promising agents for species-specific pest control.[22]

According to University of Wisconsin Professor Edwin Vedejs,[22] Wittig's 1954[21] and 1955[23] articles on the synthesis of olefins in *Chemische Berichte* were followed by "an avalanche of related discoveries establishing the Wittig alkene synthesis as a process of great versatility and generality...."[22] During the 20 years covered by the *SCI* data base, these papers received 322 and 148 citations, respectively. I imagine that Wittig's publication record would be even more impressive if the Wittig synthesis had not become accepted into "that body of knowledge that everyone takes for granted without referring to the original work."[22] This exemplifies a more general pattern which Merton has described as "obliteration by incorporation" (OBI) in the canonical knowledge of a field.[24]

In spite of this obliteration in the international literature, the *SCI* indicates that his German colleagues have been quite explicit in citing his award-winning articles. In view of the above, it is not surprising that Wittig was among 250 primary authors most-cited in the period 1961-1975.[10] In that study[12] we specifically identified the 1954 paper mentioned above as his most-cited work.

Wittig and Brown published their award-winning work in the 1950s and 1930s, respectively. The importance and impact of this work was clearly established over a decade ago. Nobel recognition in the field of chemistry generally takes at least 19 years, according to Zuckerman.[1] Why did the Nobel Committee take so long to recognize Wittig and Brown? There are undoubtedly a number of reasons, not the least of which is the competition of other great ideas and discoveries. Unless Nobel prizes are to be awarded only for recent breakthroughs, there will often be a time lag because there are so many people *of Nobel class* who have not been recognized. Zuckerman reports there has been an increase in recent years in the time lag between when a Nobelist does his or her prizewinning work and when he or she receives the award.[1] Perhaps some of the injustices of this entire procedure would be eliminated if a special international Nobel Academy could be formed to which all deserving scientists, living or dead, could be elected.

1979 Nobelists in Physics

The Nobel Assembly's announcement that Harvard University Professors Sheldon Glashow and Steven Weinberg and Imperial College of London Professor Abdus Salam had been awarded the prize in physics came as no surprise to the community of theoretical physicists.[25] And it certainly came as no surprise to us at ISI! These three researchers have long been recognized for their finding that two of the basic forces of nature—electromagnetism and the weak force, or interaction—are facets of the same phenomenon. Their theories, which continue to be tested on particle accelerators, are major contributions toward the incorporation of all physical laws into a single comprehensive framework, the "unified field theory."

The Nobel prize in physics was awarded for development of what has come to be called the Weinberg-Salam theory. This theory links the electromagnetic and weak forces. Glashow had anticipated this theory in his doctoral thesis[26] and in a 1961 article.[27] In 1970, he published a paper[28] that provided a key to its confirmation—charmed particles. Weinberg's 1967 article[29] presenting this theory and Salam's 1968 paper[30] reaching the same conclusion have had remarkable citation histories—1,550 and 1,000 citations, respectively. One wonders if the difference in citation histories is due to the artifact that Weinberg published in *Physical Review Letters*, a high impact journal,[31] whereas Salam's article appeared in the prestigious, but less widely circulated, proceedings of the Eighth Nobel Symposium, *Elementary Particle Theory*. It's also possible that physicists have cited a 1964 *Physics Letters*[32] paper in which Salam presented some of the ideas that later appeared in the 1968 paper. This paper, entitled "Electromagnetic and weak interactions," has received 181 citations.

Although all three physicists are extremely well-cited, Weinberg, with 19,230 citations, has a particularly impressive citation record. In fact, he ranked in the top hundred on both our lists of most-cited authors.[10,11] Incidentally, both the 1967[29] and 1966[33] Weinberg papers were identified in those studies.[34,12] These papers appeared more recently, along with another 1967 paper,[35] on our list of most-cited physical science articles of the 1960s.[36]

It is interesting that Glashow and Salam authored many highly cited articles[37-41] identified in our lists,[42-4] but which were not recognized by the Nobel Committee. This is not entirely surprising. As Zuckerman points out, several Nobel prizewinners have made a number of fundamental scientific discoveries which, though prize-worthy, are not mentioned in their Nobel citations.[1]

As I've mentioned before,[4] certain discoveries do not elicit an expected citation pattern because they are what is described as premature. Glashow and Salam, with citation records of 3,200 and 3,800 citations, respectively, are obviously well-recognized for their contributions to theoretical physics. In fact, Glashow's work predicting the existence of charmed particles has been described by the author in a recent *Citation Classic*.[45] But Sidney Coleman of the Stanford Linear Accelerator Center points out in *Science*[25] that relatively little attention was paid to the Nobel prizewinning work of all three researchers prior to 1971. At that time, Professor Gerard 't Hooft of the State University of Utrecht, the Netherlands, published a paper[46] that provided further mathematical proof for their theories. According to Coleman, 't Hooft's paper "...revealed Weinberg and Salam's frog to be an enchanted prince."[25] This was most significant, as a chronological analysis of citations to Weinberg's 1967 paper shows. Originally prepared by Coleman from *SCI* data, we have updated the analysis in Table 2. From 1967-71 Weinberg's paper was cited only five times, but in 1972 it received 74 citations! In contrast, the average paper covered by *SCI* received about two citations a year from 1967 to 1979.

Table 2: Citation data for: **Weinberg S.** A model of leptons. *Phys. Rev. Lett.* 19(21):1264-6, 20 November 1967.

Year	Total Citations
1967	0
1968	0
1969	0
1970	1
1971	4
1972	74
1973	167
1974	184
1975	179
1976	185
1977	272
1978	210
1979	245
1980/week 32	145

1979 Nobelists in Physiology or Medicine

The Nobel prizewinners in chemistry and physics have regularly appeared on our lists of highly cited authors and articles. However, for any number of reasons, the importance of a Nobelist's work is sometimes not reflected in our citation studies.

For example, the computerized axial tomography (CAT) scanner, for which Alan M. Cormack and Godfrey Newbold Hounsfield won the 1979 Nobel prize in physiology or medicine, is undoubtedly a significant contribution to medical science.[47]

Cormack and Hounsfield's "invention" offers a highly effective and quick technique for detecting brain tumors, birth defects, and other brain conditions, and for diagnosing a number of disorders affecting the kidney and certain lymph nodes near the kidney, abnormalities of the spine, cancer, and infection. The CAT scanner operates by beaming a rotating X-ray through a cross section of the body or brain from every angle. This information is fed into a computer that provides a picture of the slice of organ being examined. Although the CAT scanner has been in general hospital use for only seven years, it is estimated that there are 2,600 CAT scanners in the world, 1,400 of which are in the US.[48]

The winners of the physiology or medicine award, although well-cited, are not unusually highly cited authors. Hounsfield and Cormack received approximately 570 and 221 citations, respectively, in the *SCI*. While neither of these Nobelists has ever appeared on our author lists, they are well-cited in their own field when compared to their colleagues. Table 3 provides a list of most-cited authors who participated in computerized axial tomography research. The list was prepared from ISI cluster data. Hounsfield appears as the fourth most-cited author on this list. Cormack shows up farther down the list, but he is still very well cited among his peers. The first author on this list, Juan Taveras, a radiologist at Massa-

Table 3: Most-cited authors, computerized axial tomography*

Authors	Total Citations 1961-date
Taveras J M	1,098
Ambrose J	805
New P F J	691
Hounsfield G N	570
Scott W R	532
Leopold G R	506
Alfidi R J	466
Stanley R J	382
Holm H H	345
Barnett E	251
Paxton R	241
Sagel S S	226
Cormack A M	221
Baker H L	220
Stephens D H	204
Davis K R	204
MacIntyre W J	133
Sheedy P F	119
Cook S A	116
Evens R G	102
Haaga J	91
Houser O W	90
Davis D O	81
Meaney T F	74

*Based on ISI® cluster data, 1976-1978

chusetts General Hospital and Harvard University Medical School, is a co-author of several articles[49,50] on the clinical effectiveness of the CAT scanner.

Hounsfield, a research engineer for the British electronics firm, EMI Ltd., was recognized by the Nobel Committee as the "central figure"[51] in the practical development of the CAT scanner. An early pioneer in the development of solid-state computers, Hounsfield originally conceived of the CAT scanner as a result of his research on the design of computers capable of recognizing patterns. This led him to research on new X-ray techniques and, in 1967, he calculated that mathematical formulas could be used to reconstruct the internal structure of a body from a number of X-ray transmissions.[47]

Hounsfield's 1973 paper in the *British Journal of Radiology*[52] is clearly a citation classic. It has been cited over 500 times in six years. It presented descriptive information on the first CAT scanner for examining the brains of human patients. When we complete our analysis of the 1970s, this paper will undoubtedly rank among the most-cited. For example, only 800 papers have been cited over 500 times since the *SCI* was initiated. It is interesting to note that the year after it was published, Hounsfield's paper was cited only 19 times, but in 1975 it was cited 54 times, and in 1976 it was cited 110 times. It is noteworthy that James Ambrose, Atkinson Morley's Hospital, London, whom we found to be the second most-cited author in the field of computerized axial tomography (see Table 3), wrote Part 2[53] of the series in which Hounsfield's most-cited paper was Part 1. Ambrose's paper is on the clinical application of the scanner, whereas Hounsfield's was a description of the CAT system. Part 3 in this series is on the radiation generated by the CAT scanner.[54]

Since Tufts University physics Professor Alan Cormack was lauded by the Nobel assembly for his mathematical treatment of X-radiation absorption by various tissues of the body,[55] his 1963[56] and 1964[57] publications in the *Journal of Applied Physics* are clearly the most relevant. Since they are primarily mathematical, it is not entirely surprising that these papers have "only" been cited about 100 times.

What is interesting about this two-part paper is its delayed recognition in terms of citations. Table 4 gives a chronological breakdown of citations to both parts of the paper.

The articles in which Cormack presented his award-winning work received only a small number of citations after their publication in 1963 and 1964. Apparently the significance of Cormack's findings could not be appreciated until the computer technology to effectively implement the scanner became available.[47,51]

W.J. Broad points out in *Science*[58] that William H. Oldendorf, UCLA School of Medicine and VA Brentwood

Table 4: Number of different citing papers. **Cormack A M.** Representation of a function by its line integrals, with some radiological applications. *J. Appl. Phys.* 34:2722-7, 1963; II. *J. Appl. Phys.* 35:2908-13, 1964.

Year	Total Citations
1963	0
1964	0
1965	0
1966	0
1967	1
1968	0
1969	0
1970	0
1971	0
1972	2
1973	4
1974	8
1975	6
1976	10
1977	19
1978	13
1979	10
1980/week 32	8

Medical Center, wrote the first paper on the subject of radiographic tomography in *IRE* [now *IEEE*] *Transactions on Biomedical Electronics* in 1961.[59] In 1963 he received the earliest patent on this technique, entitled "Radiant energy apparatus for investigating selected areas of the interior of objects obscured by dense material."[60] Oldendorf has also shared a number of awards with Hounsfield, including the 1975 Lasker Award for his "original conception of the scanning system."

Although his initial publication on radiographic tomography is cited in Hounsfield's award-winning work,[52] Oldendorf's 1961 paper received only 36 citations from 1961 to date. The data indicate he was not well-recognized by publishing medical researchers for this contribution to radiographic tomography. This may be because the journal in which it was published is oriented toward engineers, rather than clinicians. This may also be because the title of the article uses electronic, rather than medical, jargon, and so it might not be recognized as a tomography-related article. In contrast, Oldendorf's other articles have received more than 1,500 citations during the same period. For example, his 1971 paper, "Brain uptake of radiolabeled amino acids, amines, and hexoses after arterial injection," published in the *American Journal of Physiology*,[61] is a well-cited work. One wonders what would have happened had Oldendorf published his award-winning research in a well-known radiology or medical journal.

The Nobelists in Economics

The 1979 Nobel Memorial Prize in Economic Science was awarded to Sir W. Anthony Lewis and Theodore W. Schultz for their work on problems of development in the Third World. Like the traditional economists who preceded them in winning the prize, their work has been well-cited. Schultz and Lewis have focused on the importance of a nation's agricultural, rather than industrial, sector, and on its human, rather than material, resources.

Schultz, according to his Nobel citation, was the first to systematically demonstrate how investments in education can affect productivity in agriculture as well as the economy as a whole. He and his students have demonstrated that there has been a higher yield on human capital than on physical capital in the US economy. Lewis is best known for development of two theoretical models designed to explain problems of underdevelopment. The first model addresses the relationship between wages in the agricultural and industrial sectors of developing nations, and the second demonstrates how the terms of trade between developed and underdeveloped countries affect the agricultural productivity of poorer nations.

Describing the practical application of their work, Yale University economist Gustav Ranis wrote in *Science*, "...ending the agricultural neglect and urban bias of development policy is their common message, and this message is increasingly being listened to in the Third World."[62]

The *Social Sciences Citation Index*® (*SSCI* ™) only begins with 1966. We can report that Schultz, professor emeritus at the University of Chicago, has been cited about 1,400 times since that year. His most-cited work, a book, *Transforming Traditional Agriculture*,[63] accounted for about 250 of these citations. Lewis, Princeton University, was cited over 1,050 times during the same period. His 1954 paper, "Economic development with unlimited supplies of labor,"[64] is his most-cited publication, with 215 citations. Other highly cited works by these economists include Schultz's 1961 article, "Investment in human capital,"[65] (119 citations) and Lewis' 1955 book, *The Theory of Economic Growth*,[66] (over 200 citations). To appreciate the significance of these data, consider that less than 1,000 social scientists were cited 500 or more times in the same period. In fact, we found on our *SSCI* 100 most-cited authors list[67] that only 11 economists had been cited more than 1,500 times.

These economists' records of citations are small compared to previous winners like M. Friedman, P.A. Samuelson, and K.J. Arrow. However, according to many economists,[68] neither Schultz nor Lewis is identified with a major theoretical breakthrough. The selection committee obviously felt this did not prevent them from being considered *of Nobel class*. One cannot quarrel with any attempt to reward those who work in areas that are not widely cultivated. I expect that this particular prize will have a positive impact on the number of graduate students who pursue these subjects.

There may be several reasons neither of these economists appeared on our list of highly cited *SSCI* authors, chief among these possibly being that their major works were published before the *SSCI* was created.

Within the next few months, we hope to complete our studies of the 1,000 most-cited authors for the period 1965 to 1978. It will be interesting to observe how often the Nobel selection committee agrees that some of these authors, too, are *of Nobel class*.

* * * * *

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