Tracing the Influence of JD Bernal on the World of Science through Citation Analysis

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Eugene Garfield and John Desmond Bernal at the 1958 International Conference on Scientific Information, Washington DC.

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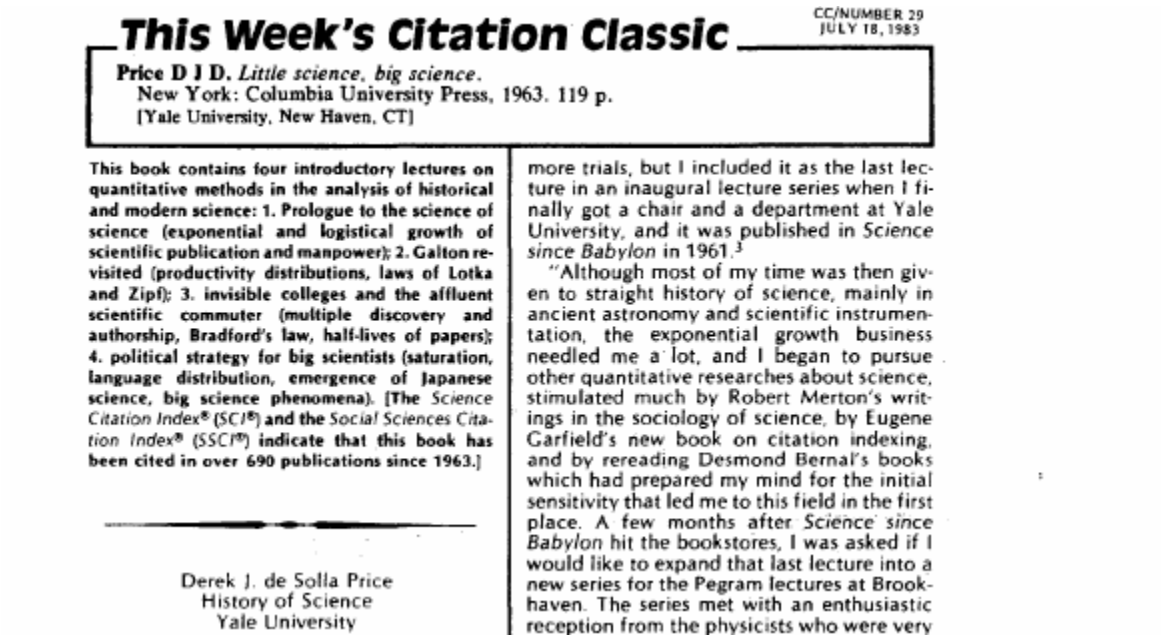
When Little Science, Big Science was designated Citation Classic status Derek Price stated that "re-reading John Desmond Bernal's books prepared my mind for the initial sensitivity that led me to this field in the first place."[1]

Slide #2 – Citation Classic Commentary by Derek Price



This Week's Citation Classic

CC/NUMBER 29
JULY 18, 1983

Price D J D. *Little science, big science.*
New York: Columbia University Press, 1963. 119 p.
[Yale University, New Haven, CT]

This book contains four introductory lectures on quantitative methods in the analysis of historical and modern science: 1. Prologue to the science of science (exponential and logistical growth of scientific publication and manpower); 2. Galton revisited (productivity distributions, laws of Lotka and Zipf); 3. invisible colleges and the affluent scientific commuter (multiple discovery and authorship, Bradford's law, half-lives of papers); 4. political strategy for big scientists (saturation, language distribution, emergence of Japanese science, big science phenomena). [The *Science Citation Index*® (*SCI*®) and the *Social Sciences Citation Index*® (*SSCI*®) indicate that this book has been cited in over 690 publications since 1963.]

Derek J. de Solla Price
History of Science
Yale University

more trials, but I included it as the last lecture in an inaugural lecture series when I finally got a chair and a department at Yale University, and it was published in *Science since Babylon* in 1961.[3]

"Although most of my time was then given to straight history of science, mainly in ancient astronomy and scientific instrumentation, the exponential growth business needled me a lot, and I began to pursue other quantitative researches about science, stimulated much by Robert Merton's writings in the sociology of science, by Eugene Garfield's new book on citation indexing, and by rereading Desmond Bernal's books which had prepared my mind for the initial sensitivity that led me to this field in the first place. A few months after *Science since Babylon* hit the bookstores, I was asked if I would like to expand that last lecture into a new series for the Pegram lectures at Brookhaven. The series met with an enthusiastic reception from the physicists who were very

By "this field" Derek meant Scientometrics. While with hindsight Price later acknowledged, in 1983, Bernal's influence, he did not mention his name either in Science Since Babylon or Little Science, Big Science .

Slide #3 – Garfield and Derek Price

Eugene Garfield and Derek DeSolla Price

Slide #4 – Contents Pages of Little Science, Big Science …. And Beyond

LITTLE SCIENCE, BIG SCIENCE….. AND BEYOND

DEREK J. DE SOLLA PRICE

(Columbia University Press, New York 1986)

CONTENTS

And yet, the opening chapter of Little Science, Big Science is entitled "A prologue to the Science of Science" that is, the quantitative study of science and, in particular, its exponential and logistical growth. Although Derek Price's memory was often flawed, he had a special way with words. Like Derek I am certain that Bernal also helped prepare my mind for the sensitivity that led me to the field of scientific information retrieved and its by-product, bibliometrics, which has evolved into Scientometrics.

Derek's explicit citational omission typifies much of Bernal's influence. Critics of citation analysis often mention these examples of "citation amnesia," as Robert K. Merton named them. When Merton and I wrote the foreword to the second edition of Little Science, Big Science, we were equally guilty of this omission. However, in spite of these lapses, citation analyses demonstrate the influences and connections between Bernal and dozens of widely recognized eminent scholars.

If time permitted, I would be tempted to simply recite my 1982 reflections on John Desmond Bernal commemorating the tenth anniversary of his death but you can read them on my website. That essay enunciated my appreciation of his life and made my connection with Bernal permanent by the establishment of the annual Bernal Award of the Society for the Social Studies of Science known as 4S.[2]

Slide #5 – 4S Bernal Award Recipients

Recipients of the John Desmond Bernal Award of the Society for Social Studies of Science (4S)

1981 - Derek J. de Solla Price
1982 - Robert K. Merton
1983 - Thomas S. Kuhn
1984 - Joseph Needham
1985 - Joseph Ben-David
1986 - Michael Mulkay
1987 - Christopher Freeman
1988 - Dorothy Nelkin
1989 - Gerald Holton
1990 - Thomas Hughes
1991 - Melvin Kranzberg
1992 - Bruno Latour
1993 - David Edge
1994 - Mary Douglas
1995 - Bernard Barber
1996 - David Bloor
1997 - H.M. Collins
1998 - Barry Barnes
1999 - Martin J.S. Rudwick
2000 - Donna Haraway
2001 - Steven Shapin
2002 - Michel Callon
2003 - Helga Nowotny
2004 - Sheila Jasanoff
2005 - Donald MacKenzie
2006 - Wiebe Bijker

Derek Price was the first recipient of that award. In his acceptance speech, he acknowledged the impact Bernal had on his career, noting that his work in the social theory of science was partly inspired by Bernal and he stated that "I am doubly honored by this award commemorating a person for whom I had much love, and from whom I learned a little about scholarly style, good appetite and some sense of social and political responsibility."

It is significant that the first winners of this award, which is still sponsored by Thomson – ISI, included Robert K. Merton, Thomas Kuhn and Joseph Needham who are among the most influential and most-cited scholars in the history, sociology and philosophy of science. It is not surprising that these names are also linked through citation analysis to the seminal work of Bernal through his 1939 classic The Social Function of Science.[3]

Slide #6. Contents Page of Bernal's Social Function of Science

CONTENTS PAGE OF BERNAL'S SOCIAL FUNCTION OF SCIENCE.

THE SOCIAL FUNCTION OF SCIENCE

J.D. BERNAL

**The M.I.T. Press, Massachusetts Institute of Technology,
Cambridge, Massachusetts, and London, England**

First M.I.T. Press Paperback Edition, March 1967

CONTENTS

Most of you are familiar with the Science Citation Index® which is used mainly in its electronic form on the Web of Science®(WoS) portal. It is routine for scholars and librarians to obtain a picture of the publication output of scientists and their institutions as well as a detailed analysis of the citation frequencies for individual papers. Among other quantitative measures, the Web of Science also displays the so-called H-Index which is now a popular though often crude ranking developed by physicist Jorge Hirsch.[2] Time does not permit me to discuss the methodology involved in these and other rankings or elaborate in-depth on the technique I call algorithmic historiography mentioned in the abstract of my talk. . The software called HistCite™ uses the output of searches on the Web of Science database to help users identify and visualize key developments in the evolution of scientific topics or invisible colleges… to use the term borrowed by Derek Price from the early history of science and popularized by Diana Crane's book, the Invisible Colleges[3].

Slide # 7 Cited References in the HistCite file for Bernal's Social Function of Science

Most cited references in the collection of papers citing the Social Function of Science

1	BERNAL JD, 1939, SOCIAL FUNCTION SCI	319
2	KUHN TS, 1962, STRUCTURE SCI REVOLU	61
3	BERNAL JD, 1967, SOCIAL FUNCTION SCI	47
4	MERTON RK, 1973, SOCIOLOGY OF SCIENCE	47
5	PRICE DJD, 1963, LITTLE SCI BIG SCI	44
6	MERTON RK, 1938, SCI TECHNOLOGY SOC 17	31
7	RAVETZ JR, 1971, SCIENTIFIC KNOWLEDGE	27
8	ZIMAN J, 1968, PUBLIC KNOWLEDGE SOC	25
9	ROSE H, 1969, SCIENCE SOCIETY	24
10	MERTON RK, 1957, SOCIAL THEORY SOCIAL	23
11	BARBER B, 1952, SCI SOCIAL ORDER	22
12	HAGSTROM WO, 1965, SCIENTIFIC COMMUNITY	22
13	LATOUR B, 1979, LABORATORY LIFE SOCI	22

14	BUSH V, 1945, SCI ENDLESS FRONTIER	21
15	BENDAVID J, 1971, SCI ROLE SOC COMP ST	19
16	MARCUSE H, 1964, ONE DIMENSIONAL MAN	19
17	BERNAL JD, 1954, SCIENCE IN HISTORY	18
18	BLOOR D, 1976, KNOWLEDGE SOCIAL IMA	17
19	POLANYI M, 1951, LOGIC LIBERTY	15
20	STORER N, 1966, SOCIAL SYSTEM SCIENC	15
21	COLE JR, 1973, SOCIAL STRATIFICATIO	14
22	PRICE DJD, 1961, SCIENCE SINCE BABLYON	13

In the case of Bernal's "Social Function of Science" the software has created a mini citation index of the 16,000 references included in the 364 papers that have explicitly cited the book.

Using these techniques combined with editing the variations or errors in author citations, one can obtain a preliminary indicator of Bernal's substantial impact in the science policy area. His overall scientific work has been cited explicitly in the in over 8,000 papers. And these figures do not tell us how often authors of books or monographs have referred to his work. We will be able to get a more accurate measure when Google Scholar and other search engines provide full-text access to book material. Indeed, as is seen in SLIDE # 5, the works that are most often co-cited with Bernal's Social Function of Science are other books such as Kuhn's Structure of Scientific Revolutions, Merton's 1973 Sociology of Science and his classic 1938 – Science, Technology and Society in 17th-century England as well as Price's Little Science, Big Science. Also noteworthy is Ravetz's 1971 book on Scientific Knowledge and John Ziman's 1968 Public Knowledge: Essay Concerning the Social Dimension of Science. Cambridge University Press.

Slide #8 – Timeline of most-cited references sorted by publication year.

Slide #8 shows part of the 200 books and papers most-referenced in the 364 papers that have cited Social Function of Science. A simple re-sort of this ranked cited reference list provides a time line in the development of the science of science.

Most cited papers sorted chronologically

1	BERNAL JD, 1939, SOCIAL FUNCTION SCI	319
2	KUHN TS, 1962, STRUCTURE SCI REVOLU	61
3	BERNAL JD, 1967, SOCIAL FUNCTION SCI	47
4	MERTON RK, 1973, SOCIOLOGY OF SCIENCE	47
5	PRICE DJD, 1963, LITTLE SCI BIG SCI	44
6	MERTON RK, 1938, SCI TECHNOLOGY SOC 17	31
7	RAVETZ JR, 1971, SCIENTIFIC KNOWLEDGE	27
8	ZIMAN J, 1968, PUBLIC KNOWLEDGE SOC	25
9	ROSE H, 1969, SCIENCE SOCIETY	24
10	MERTON RK, 1957, SOCIAL THEORY SOCIAL	23
11	BARBER B, 1952, SCI SOCIAL ORDER	22
12	HAGSTROM WO, 1965, SCIENTIFIC COMMUNITY	22
13	LATOUR B, 1979, LABORATORY LIFE SOCI	22
14	BUSH V, 1945, SCI ENDLESS FRONTIER	21
15	BENDAVID J, 1971, SCI ROLE SOC COMP ST	19
16	MARCUSE H, 1964, ONE DIMENSIONAL MAN	19
17	BERNAL JD, 1954, SCIENCE IN HISTORY	18
18	BLOOR D, 1976, KNOWLEDGE SOCIAL IMA	17
19	POLANYI M, 1951, LOGIC LIBERTY	15
20	STORER N, 1966, SOCIAL SYSTEM SCIENC	15
21	COLE JR, 1973, SOCIAL STRATIFICATIO	14
22	PRICE DJD, 1961, SCIENCE SINCE BABLYON	13

Slide # 9 HistCite Collection of 8,500 papers citing J.D. Bernal

The collection of papers citing JD Bernal sorted chronologically

#	Author / Title / Journal	LCS	GCS
1	1 Bernal JD The structure of graphite PROCEEDINGS OF THE ROYAL SOCIETY OF LONDON SERIES A-CONTAINING PAPERS OF A MATHEMATICAL AND PHYSICAL CHARACTER. 1924 DEC; 106 (740): 749-773	163	163
2	2 Bernal JD On the interpretation of X-rays, single crystal, rotation photographs PROCEEDINGS OF THE ROYAL SOCIETY OF LONDON SERIES A-CONTAINING PAPERS OF A MATHEMATICAL AND PHYSICAL CHARACTER. 1926 NOV; 113 (763): 117-160	99	99
3	3 Gibbs RE The polymorphism of silicon dioxide and the structure of tridymite PROCEEDINGS OF THE ROYAL SOCIETY OF LONDON SERIES A-CONTAINING PAPERS OF A MATHEMATICAL AND PHYSICAL CHARACTER. 1926 DEC; 113 (764): 351-368	1	10
4	4 Hendricks SB The crystal structure of potassium di-hydrogen-phosphate AMERICAN JOURNAL OF SCIENCE. 1927; 14 (82): 269-287	0	19
5	5 Jaeger FM, van Melle FA Investigations into the constitution of artificial ultramarines II On ultramarine-blue with high silica-content and on silver silversodium-selenium-and silberselenium-ultramarines PROCEEDINGS OF THE KONINKLIJKE AKADEMIE VAN WETENSCHAPPEN TE AMSTERDAM. 1927; 30 (1/5): 479-498	0	7
6	6 Morse JK Atomic lattices and atomic dimensions PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES OF THE UNITED STATES OF AMERICA. 1927; 13: 227-232	1	5
7	7 Morse JK The molecular structures of methane PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES OF THE UNITED STATES OF AMERICA. 1928; 14: 166-171	0	2

In the previous slides we have limited our analysis to Bernal's 1939 book. Slide #9 provides a brief view of the overall citation record for J.D. Bernal's scientific work. Slide #9 provides the initial chronological display of the collection which includes the 8,500 papers citing his work as well as Bernal's own papers…..

Slide # 10 HistCite collection sorted by Global Citation Score (GCS)

Highly Cited Papers in the collection of papers citing J.D. Bernal

#	Date / Author / Journal	LCS	GCS
1	BROOKS BR, BRUCCOLERI RE, OLAFSON BD, STATES DJ, SWAMINATHAN S, et al. CHARMM - A PROGRAM FOR MACROMOLECULAR ENERGY, MINIMIZATION, AND DYNAMICS CALCULATIONS JOURNAL OF COMPUTATIONAL CHEMISTRY. 1983; 4 (2): 187-217	16	6879
2	JORGENSEN WL, CHANDRASEKHAR J, MADURA JD, IMPEY RW, KLEIN ML COMPARISON OF SIMPLE POTENTIAL FUNCTIONS FOR SIMULATING LIQUID WATER JOURNAL OF CHEMICAL PHYSICS. 1983; 79 (2): 926-935	184	5929
3	MARCUS RA THEORY OF OXIDATION-REDUCTION REACTIONS INVOLVING ELECTRON TRANSFER .1. JOURNAL OF CHEMICAL PHYSICS. 1956; 24 (5): 966-978	15	2704
4	FRANK HS, EVANS MW FREE VOLUME AND ENTROPY IN CONDENSED SYSTEMS .3. ENTROPY IN BINARY LIQUID MIXTURES - PARTIAL MOLAL ENTROPY IN DILUTE SOLUTIONS - STRUCTURE AND THERMODYNAMICS IN AQUEOUS ELECTROLYTES JOURNAL OF CHEMICAL PHYSICS. 1945; 13 (11): 507-532	192	2353
5	Bernal JD, Fowler RH A theory of water and ionic solution, with particular reference to hydrogen and hydroxyl ions JOURNAL OF CHEMICAL PHYSICS. 1933 AUG; 1 (8): 515-548	1947	1947
6	GRAHAME DC THE ELECTRICAL DOUBLE LAYER AND THE THEORY OF ELECTROCAPILLARITY CHEMICAL REVIEWS. 1947; 41 (3): 441-501	17	1687
7	RICHARDS FM AREAS, VOLUMES, PACKING, AND PROTEIN-STRUCTURE ANNUAL REVIEW OF BIOPHYSICS AND BIOENGINEERING. 1977; 6: 151-176	17	1583
8	HUBBELL WL, MCCONNEL.HM MOLECULAR MOTION IN SPIN-LABELED PHOSPHOLIPIDS AND MEMBRANES JOURNAL OF THE AMERICAN CHEMICAL SOCIETY. 1971; 93 (2):	3	1565

Ranking by the Global Citation Score (GCS), one sees in SLIDE # 10 a fraction of the influential citing works which themselves were cited over 1,000 times. One of the characteristics of Nobel class scientists like Einstein, Pauling, Watson and others, is that their work is cited in turn by highly cited authors and usually over a long period of time. Thus it can truly be said that they are standing on the shoulders of giants.

Slide #11. Continuation of Papers Cited over 3,000 Times

Highly cited papers in the collection of papers citing JD Bernal, continued

#	Date / Author / Journal	LCS	GCS
11	CASPAR DLD, KLUG A PHYSICAL PRINCIPLES IN CONSTRUCTION OF REGULAR VIRUSES COLD SPRING HARBOR SYMPOSIA ON QUANTITATIVE BIOLOGY. 1962; 27: 1-&	39	1263
12	DEHEER WA, CHATELAIN A, UGARTE D A CARBON NANOTUBE FIELD-EMISSION ELECTRON SOURCE SCIENCE. 1995 NOV 17; 270 (5239): 1179-1180	1	1263
13	KAUZMANN W THE NATURE OF THE GLASSY STATE AND THE BEHAVIOR OF LIQUIDS AT LOW TEMPERATURES CHEMICAL REVIEWS. 1948; 43 (2): 219-256	59	1218
14	NEMETHY G, SCHERAGA HA STRUCTURE OF WATER AND HYDROPHOBIC BONDING IN PROTEINS .1. A MODEL FOR THERMODYNAMIC PROPERTIES OF LIQUID WATER JOURNAL OF CHEMICAL PHYSICS. 1962; 36 (12): 3382-&	179	1209
15	THIEL PA, MADEY TE THE INTERACTION OF WATER WITH SOLID-SURFACES - FUNDAMENTAL-ASPECTS SURFACE SCIENCE REPORTS. 1987; 7 (6-8): 211-385	30	1208
16	PAULING L ATOMIC RADII AND INTERATOMIC DISTANCES IN METALS JOURNAL OF THE AMERICAN CHEMICAL SOCIETY. 1947; 69 (3): 542-553	16	1114
17	BIRCH F ELASTICITY AND CONSTITUTION OF THE EARTH INTERIOR JOURNAL OF GEOPHYSICAL RESEARCH. 1952; 57 (2): 227-286	33	1089
18	FLORY PJ PHASE EQUILIBRIA IN SOLUTIONS OF ROD-LIKE PARTICLES PROCEEDINGS OF THE ROYAL SOCIETY OF LONDON SERIES A-MATHEMATICAL AND PHYSICAL SCIENCES. 1956; 234 (1196): 73-89	44	1076
19	FOX TG, FLORY PJ 2ND-ORDER TRANSITION TEMPERATURES AND RELATED PROPERTIES OF POLYSTYRENE .1. INFLUENCE OF MOLECULAR	16	1011

A near universal characteristic of Nobel-class science which we reported back in 1965[6] is not only that Nobel scientists are prolific – publishing 5 or 6 times the average – but their work is cited 30 to 50 times the average. Bernal's publication output is not typical. Among other reasons, it is well known that he did not add his name to countless papers that in today's more self-centered world would have increased his personal bibliography severalfold. In this sense, Blaise Cronin is correct to seek a way to modify the ranking of scholars by measuring tacit citation in the form of published or other acknowledgements.[7]

I first corresponded with Bernal in 1962, when the *Science Citation Index*® (*SCI*) was in its infancy even though we had already met in person in 1958 at the International Conference on Scientific Information in Washington. I wrote Bernal to ask his opinion of the fledgling *SCI*. He was pleased to hear from me and thought the idea was exciting and of potentially great value, but had reservations about the feasibility of executing the project. When we demonstrated that it was indeed possible, having produced the experimental *Genetics Citation Index*, Bernal was delighted and said " I think [it is] going to provide something really new and valuable in documentation material."[8] Later, he agreed to serve on the SCI editorial advisory board.

Slide # 12 J.D. Bernal's Review of SCI in Science Progress

JD Bernal's review of the SCI in *Science Progress*, 1965

Essay reviews

Science citation index

Philadelphia: Institute for Scientific Information

When I first heard about the *Science Citation Index* from Dr Garfield himself over 2 years ago, I could not quite imagine what it would be like: now I have been studying it for some time and can see something of what Dr Garfield means in his idea of its being a new dimension in indexing. Indeed, I was proposing to do an article on it for *Science Progress*, but the volumes were of such weight and density of information that they could not be treated in a hurry. I resolved to give it a test in some detail and then to make a quantitative assessment. Meanwhile *Science Progress* changed Editors and there was no time left to produce this article in advance of the review already prepared by Professor Ziman and published in the previous issue.

The value of the *Science Citation Index* was immediately apparent to me because I had tried to do the same thing in reverse order in writing about various aspects of the history of science. The publications of science effectively form a network of mutual reference which can be traced out from any particular point from which one chooses to start. It is a graph in the mathematical sense. The *Citation Index* is constructed so as to produce an almost infinite number of such graphs. Its value as an index is another matter altogether. The real question is, what is such an index needed for? If it is simply to find out where a certain paper is, the existing one-way indices contained in the Abstracts should be sufficient. However, an index has more functions than this: it should give the relationships of any given paper to all other papers that are appearing, not necessarily on the same subject or in the same detailed field but anywhere in science, and this function the *Science Citation Index* admirably fulfils.

Nevertheless, the criticism as to coverage which has been made by Professor Ziman, is, I think, quite a valid if a temporary one. I was also immediately struck on looking at the index for 1961, with the peculiar and restricted list of its source journals, though there was a notable improvement in 1964. Remember, the Index contains two kinds of lists of references, those of the source papers and those of the papers quoted. The latter is universal. Every paper cited in a source

About a year later he published a review of SCI in Science Progress[9] which also included a separate review by John Ziman. I had met Professor Ziman when I gave a lecture in London about the SCI. He pointed out the initial glaring omission of the Philosophical Magazine of which he was editor. We corrected that embarrassing

situation shortly thereafter when we realized it was an often cited journal in materials science.

I had known of Bernal for a long time before we met.

As a teenager, one of my uncles gave me a copy of The Social Function of Science. I had just finished high school, and took it with me to the University of Colorado in 1942 where it was the subject of much discussion. Since it was wartime the stigma of his Marxist political views was less evident than during the post war years. Five years later I felt the impact of Bernal again when I joined the Welch Medical Library Machine Indexing Project at Johns Hopkins University in 1951. Bernal had been a significant factor in organizing the 1946 Royal Society Empire Science Conference[10] which led to the 1948 Royal Society Scientific Information Conference.[11] The proceedings of this conference became a bible for me as a fledgling investigator. In particular, his idea of a centralized reprint center was in my thoughts when I first proposed the as yet nonexistent SCI in Science in 1955.[12]

Many scientists and documentalists I met at Welch participated in the 1948 conference. They included Ralph Shaw, G.M. Dyson, Mortimer Taube, B.C. Vickery, Robert Fairthorne, Jason Farradane, D. J. Urquhart, Watson Davis and James Murray Luck, the namesake of the National Academy of Sciences annual Award for Scientific Reviewing and the founder of Annual Reviews.

I have always felt honored by my association with Professor Bernal. After his death I met his friend and admirer Maurice Goldsmith and often visited the Science Policy Foundation in London. Goldsmith often related Bernal's sharp scientific abilities and early curiosity. From Maurice I learned that at the age of seven Bernal tried to make hydrogen but managed, instead, to produce a magnificent explosion. I empathized with that event having set off a few explosions myself as a young chemist.[13]

Opinions about Goldsmith's brief biography of Bernal were quite strong – some liked it, while others, like Dorothy Hodgkin, tried to discredit it.[14] John Maddox, editor of Nature, commented on her review as follows: "Polemic is...part (but ideally a small part) of book review columns. Professor Dorothy Hodgkin's review is more puzzling. Goldsmith set out to write a biography of one of his heroes, and was savaged for his pains by another hero-worshipper, his reviewer. No doubt the book is, as Hodgkin says, "confused and inaccurate". It is also, however, a good book in

the sense of being a good read and also (for a hero-worshipper) honest in that it deals with the warts as well as the achievements—sexual proclivities, ambivalence about Lysenko and all that. Maybe Goldsmith's book is "not the book that is needed about Bernal", but it is the only book we have."[15] Fortunately the situation has changed since then and we have Andrew Brown's eminently readable biography.

Bernal's paper on the structure of graphite was his first major success.[16] The SCI for 1925 to 1960 records only a portion of its citation impact since the SCI does not cover all of the relevant journals and books for those four decades. Stemming from his work with graphite was another, even larger, success. Bernal had found, while working with graphite, that the process of indexing the photographs taken of the crystal was very tedious. He developed a chart to simplify the process of classifying the reflections. The paper describing the theory of X-ray diffraction is considered one of his most important by many. [17] Professor Hodgkin stated that it "is as useful reading today for many beginners in crystallography as it was in [1927]."[18]

Goldsmith, borrowing from C.P. Snow and Bragg, expands still further on Bernal's gift for inspiration: "His strength lay in causing other minds to light up. Most of the leading names in Britain working on molecular biology and the analysis of Protein crystals were either Bernal's associates or students. Wherever he went he left behind intellectual "fall out", providing more than sufficient for a lifetime of scientific work. If one traced back almost any fruitful line of crystallographic work it would be found that Bernal assisted at its conception, but, significantly, left the child to be brought up by foster-parents."[19]

In 1945 Bernal was awarded the highest honor of the Royal Society – the Royal Medal. He served as President of the International Union of Crystallography from 1963 to 1966. Although he did much work of Nobel class, he never won the prize himself. That was a fact that surprised many. According to J.G. Crowther, a British science writer, ''Bernal's demonstration that the accepted formula for the steroids was wrong — which led to the correct path to the synthesis of sex hormones - should have been sufficient in itself to earn him a share in a Nobel Prize."[20] Wolfie Traub, one of Bernal's students now at the Weizmann Institute in Israel, said: "Nobel Prizes are generally given for important scientific work based on far-sighted scientific vision and carefully planned, sustained and orchestrated teamwork. Bernal had little patience for detail and careful planning. He never

organized a scientific team though he inspired many protégés and he certainly had brilliant scientific vision and insight. As a young man of 30 he used quite simple X-ray measurements to show that the sterol structure, derived by the Nobel Prizewinners Wieland and Windaus, was wrong. It took another half dozen years before Bernal's protégés Crowfoot (later Hodgkin) and Carlisle determined the correct structure. He showed that proteins in crystals must have well defined structures and how it was possible to obtain X-ray data defining these structures. It took Perutz and Kendrew a quarter of a century to actually determine the first protein structures by analyzing such data. In 1938 Bernal and Fankuchen showed that even viruses, complete living individuals, have ordered structures in crystals. Many fine scientists have continued this work and the first detailed structures of viruses have only appeared in the last two or three years.

Bernal's interests moved from one great scientific problem to another, from science to politics to philosophy to history to sociology. He was always writing, traveling, lecturing, advising, posing problems and making provocative suggestions. He didn't have the patience to earn a Nobel Prize, but those of his protégés who did... would be the first to acknowledge his greatness.[21]

Traub's sentiments were echoed by Alan Mackay during a visit to ISI decades ago. He observed that Bernal's contributions to science were diffuse, and "diffuse contributions do not receive the Nobel Prize."[22]

As mentioned at the outset, in 1981, to honor Bernal and his pioneering work in the social study of science, the 4S, together with ISI, established the Bernal Award. The 4S, which was founded in 1975, is an international society dedicated to promoting "research, learning and education in the social studies of science." According to then 4S President Arnold Thackray, now President of the Chemical Heritage Foundation in Philadelphia, the award "recognizes outstanding scholarly achievement in the social studies of science, without restriction of field or nationality." The award is the society's highest honor, and is meant to recognize a scholar's achievement over a period of time, rather than a single work. Thomson-ISI continues to provide financial support for the award.

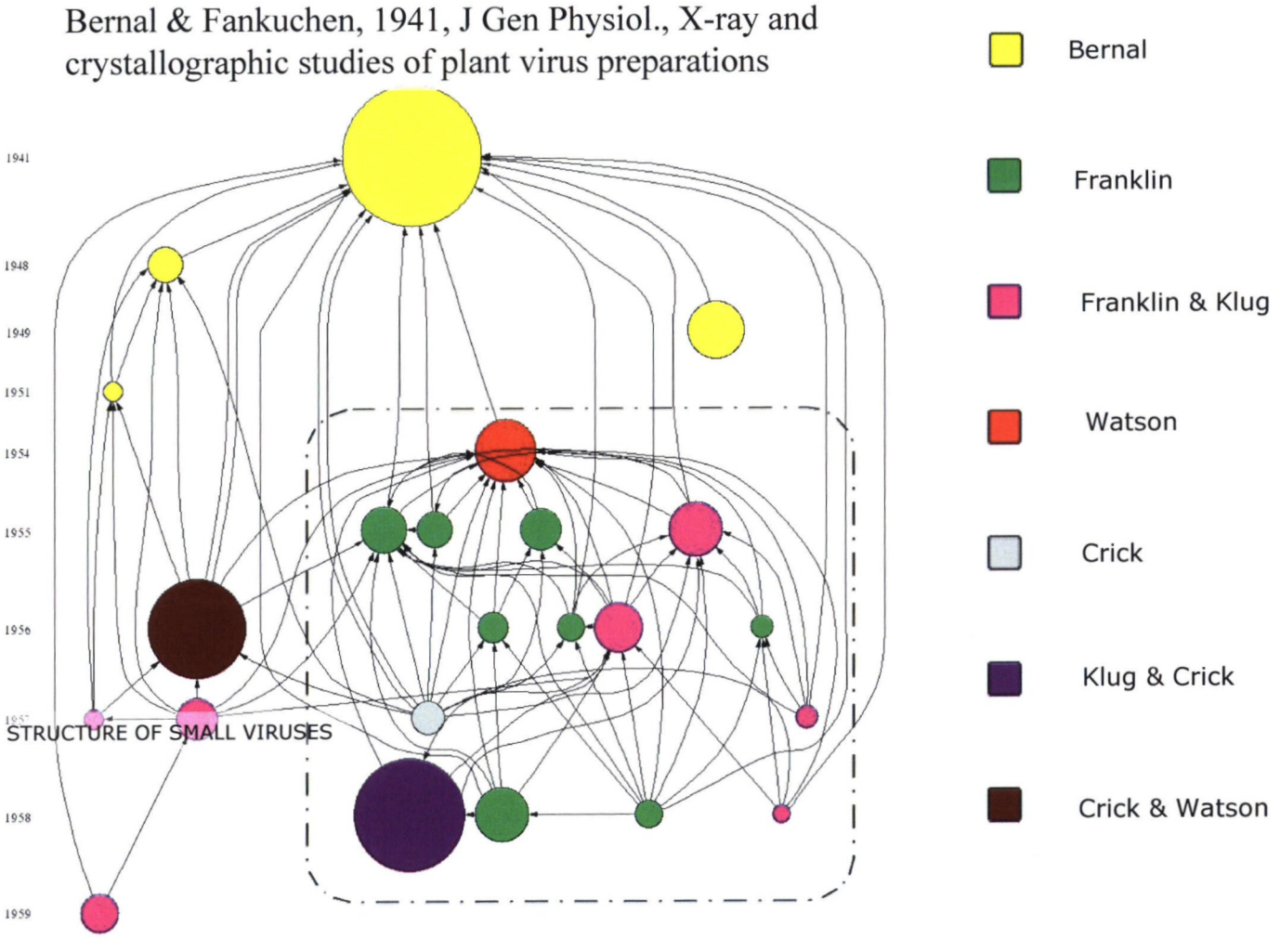
Even before the 4S Award was established, I felt the need to honor Bernal. I dedicated the first published volume of the SCI Journal Citation Reports®, to Bernal….''Dedicated to the memory of the late John Desmond Bernal, whose insight into the societal origins and impact of science inspired an interest that became a career."[23]

Incidentally, in an appendix to The Social Function of Science, Watson Davis, Science Service, argued for the creation of what could be called a predecessor to ISI, an organization he called the "Scientific Information Institute." This organization would be concerned with the "utilization and development of methods of publishing, duplicating, indexing, selecting and distributing scientific information and bibliography that are novel in their application to this problem."

Bernal's achievements are as meaningful today as ever before. Bernal's understanding of science especially transcended his own time. In fact, he was way ahead of his time. The final paragraphs from The Social Function of Science illustrate his particular genius.

"In science men have learned consciously to subordinate themselves to a common purpose without losing the individuality of their achievements. Each one knows that his work depends on that of his predecessors and colleagues, and that it can only reach its fruition through the work of his successors. In science men collaborate not because they are forced to by superior authority or because they blindly follow some chosen leader, but because they realize that only in this willing collaboration can each man find his goal, not orders, but advice, determines action. Each man knows that only by advice, honestly and disinterestedly given, can his work succeed, because such advice expresses as near as may be the inexorable logic of the material world, stubborn fact. Facts cannot be forced to our desires, and freedom comes by admitting this necessity and not by pretending to ignore it. These are things that have been learned painfully and incompletely in the pursuit of science. Only in the wider tasks of humanity will their use be found."

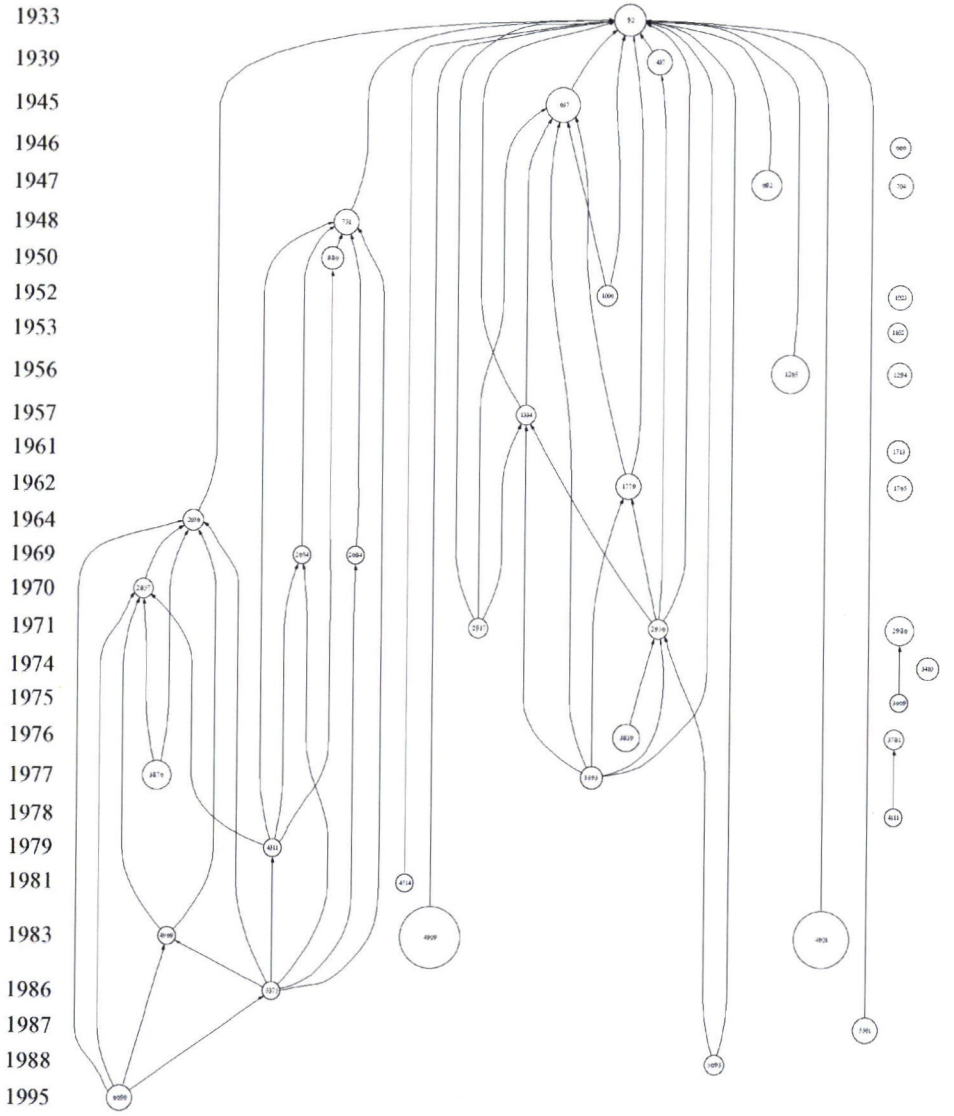
Historiograph showing connections between Bernal & Franklin et al.



Papers on the tobacco mosaic virus

Slide # 14 Historiograph of 40 Highly Cited Papers which cite Bernal

Historiograph of 40 highly cited papers (1933-1995) which cite JD Bernal



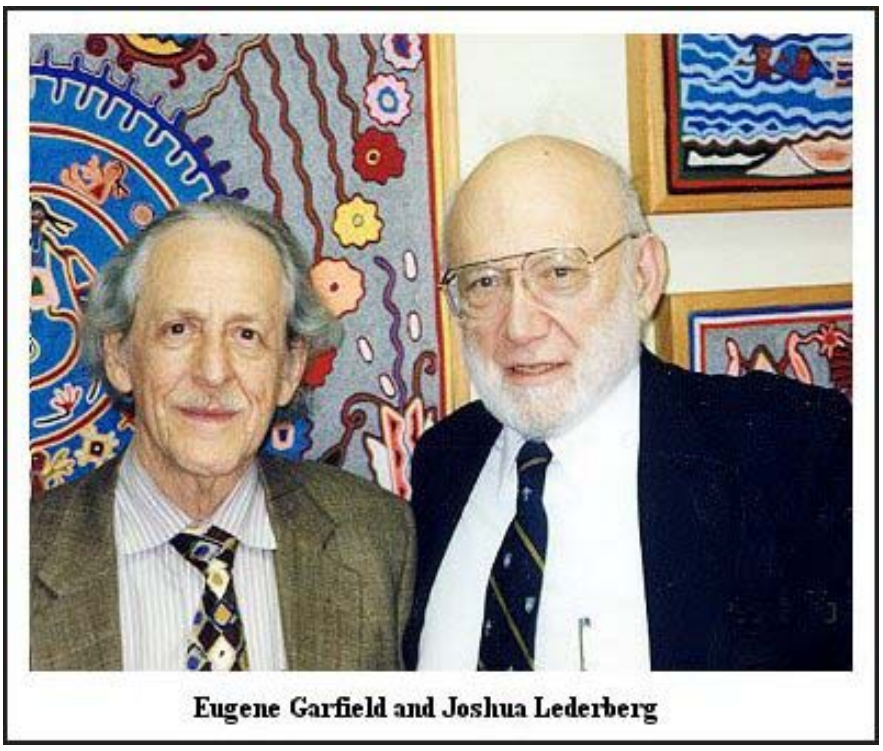
Before closing, I would just like to present a selection of historiographs which trace the link between Bernal and the work of Rosalind Franklin and others.

Slide #15 – Photograph of Bernal in 1971

Let me conclude by reminding you I was not trained as an historian or sociologist. The Science Citation Index was not planned as a tool for science evaluators. Rather, SCI was designed to improve the sharing of knowledge and efficient dissemination and retrieval of scientific information. Although I had an inkling of the impact factor in 1954 it was the later association with mentors like Robert K. Merton, Harriet Zuckerman and other social scientists that made me appreciate its value for science policy.

Slide #16 – Photograph of Garfield, Merton and Zuckerman

Slide # 17 – Photograph of Garfield and Lederberg



Eugene Garfield and Joshua Lederberg

They were also influenced by the work of Bernal as was Joshua Lederberg, who recognized Bernal's seminal ideas in an essay on "The social function of the scientist: The ethics of truth-telling"[24] on the 50th anniversary of The Social Function of Science.

In my correspondence files there are letters to and from Merton and Bernal written in 1961. Bernal mentions Science since Babylon and expresses concern about the unwitting replication of research. Bernal said "we have long since passed the point where for most parts of science it is a lot easier to discover something new than to find out whether it has been discovered before. I mean easier in the sense of the actual amount of labour employed in carrying out an experiment against labour employed in looking up references in libraries. This is a technical fault which when things get bad enough may indeed be put right. I have made some efforts myself to see that this is done." A few years later John Martyn estimated that 25% of scientists surveyed experienced unwitting duplication of research. One hopes this has been reduced significantly by advances in information technology in the past half century and satisfies Bernal's hope for a vastly more efficient worldwide sharing of scientific information.

Slide #18 - Tracing the influence of JD Bernal on the world of science through citation analysis

Tracing the influence of JD Bernal on the world of science through citation analysis

Eugene Garfield
Chairman Emeritus, ISI; President, The Scientist LLC

here to see the index page of all Bernal HistCites

http://garfield.library.upenn.edu/histcomp/index-bernal.html

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