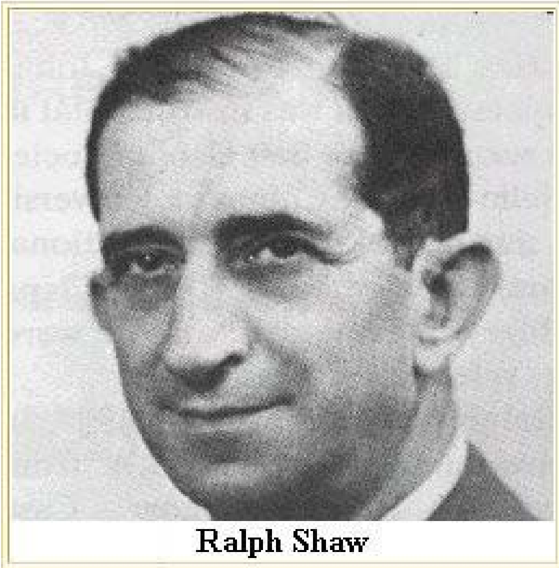
On the Shoulders of Giants – Tracing the impacts of information retrieval systems on science policy

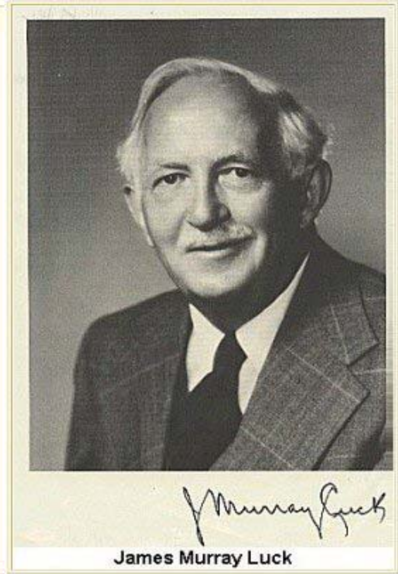
Presented by
Eugene Garfield
http://eugenegarfield.org
garfield@codex.cis.upenn.edu

60th Anniversary Celebration of
Department of Energy
Office of Scientific and Technical Information
Oak Ridge, TN - September 18, 2007

The Office of Scientific and Technical Information (OSTI) was about five years old when I first entered the field of scientific documentation in 1951. The launch of *Nuclear Science Abstracts* and OSTI in 1947 coincides with a key event in the history of science information systems – the Royal Society Conference on Scientific Information held in London (1948) inspired by the polymath John Desmond Bernal about whom I shall say more later.

SLIDE #1 Bernal and Garfield
Eugene Garfield and John Desmond Bernal at the 1958
International Conference on Scientific Information, Washington DC.





SLIDE #2 Ralph Shaw SLIDE #3 James Murray Luck

Representing the United States were Ralph Shaw, Mortimer Taube, Watson Davis and J. Murray Luck – the founder of Annual Reviews. Some of the British information scientists were pioneers like Robert Fairthorne and Jason Farradane.

Cyril Cleverdon on the left

4

SLIDE #4 Cyril Cleverdon

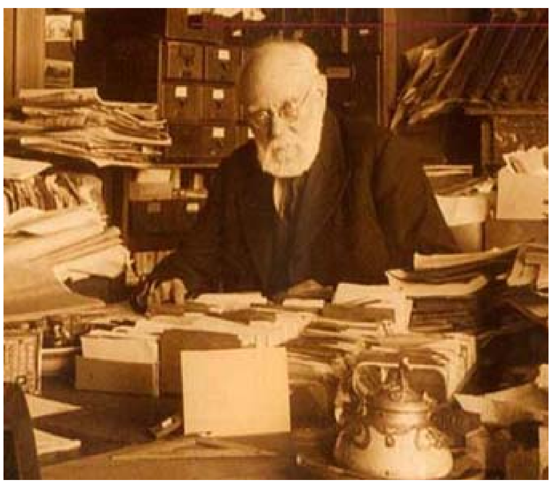
I met some of them later at the 1957 International Conference on Classification in Dorking and then would meet JD Bernal at the International Conference on Scientific Information in Washington D.C. in 1958 – six years after the first Atom Bomb test.

When I asked Sharon Jordan what would be an appropriate topic to discuss at this celebration, she seemed preoccupied with the notion that I could tell you how the field of scientific information systems has affected the world of science. That information is the life blood of scientific discovery, seems axiomatic. I have often repeated that truism but like so many other common sense assumptions – like the virtues of motherhood – it is difficult to prove. There is a comparable belief that is also difficult to prove. I serve on the Board of the non-profit advocacy organization called Research!America (www.researchamerica.org). Its main goal is to educate the public and through them, the members of Congress that medical and scientific research should be expanded -- not only because scientific discovery and curing disease are important to mankind , but also because basic and biomedical research has positive economic and social impacts. Indeed, Research!America sponsors an annual award to scholars who have demonstrated the economic benefits of biomedical research (http://garfield.library.upenn.edu/researchamerica/award.html)
We have no comparable award for demonstrating the impact of scientific and technical information systems on science progress.

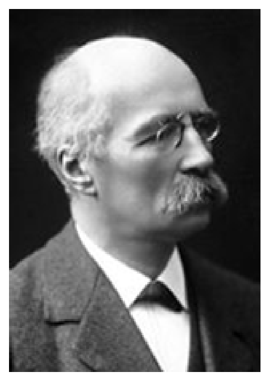
Economists like Edward Mansfield have provided evidence that investments in research provide a 25% return. But that notion is not yet universally accepted or we would not be constantly fighting to maintain the federal commitment to basic research budgets. The first five winners of the Research!America award have each published evidence to demonstrate the claim of economic impact by placing a monetary value on human life. Not only is that that notion not an accepted tenet of science policy. Rather, there are still naysayers who argue we spend too much on research. If not, the research budgets for NIH, NSF, NASA and DOE would be increased automatically every year. In spite of the widespread public belief in the positive impact of research, supported by R!A consumer surveys, and especially biomedical research, the U.S. is spending a lower percentage of its GNP on research than other countries, and less than we did in earlier years. The latest NAS report called this to the attention of the President. The last approved federal budget was slightly in excess of the already reduced amounts and does not keep up with inflation. . It is relevant to mention here that small countries like Israel and Ireland, with their high investment in innovative research, have become economic power houses.

How can we demonstrate the impact of scientific information systems on the growth of science? This is, of course, a significant problem for science policy analysts. Under the leadership of Alvin M. Weinberg, the former director of Oak Ridge Laboratory, the President's Science Advisory Committee in 1961 issued the so called Weinberg Presidential Commission Report[1] affirming the importance of science information systems. Members of the Panel on Science Information (page 51) included, among others, Nobelists Eugene Wigner, John Bardeen, and Joshua Lederberg. Noteworthy is the recognition given to Francois Kertesz of Oak Ridge National Laboratory who recorded and edited the panel proceedings. To my knowledge no one ever challenged the panel's recommendations. But the report did not attempt to demonstrate a correlation between improved information activities and science growth and progress. Science policy analysts generally assume that growth can be estimated by monitoring publication productivity.

Those of us who were trained in chemistry have been taught that access to the record of past scientific research (the literature) is essential to avoid unwitting duplicaton. Without efficient information retrieval, chemical research would be slow and even more expensive. Who would want to unintentionally repeat the research that has been reported over the past 150 years? Yet in 1965 John Martyn of ASLIB in the U.K. reported on a study in the *New Scientist* that 25% of published research is, in fact, unwitting duplication.[2] The implicit value of scientific information activities is reflected in the market place because the worldwide scientific community pays billions each year for access to what was described as the "World Brain" by H.G. Wells in 1938.[3]



Paul Otlet

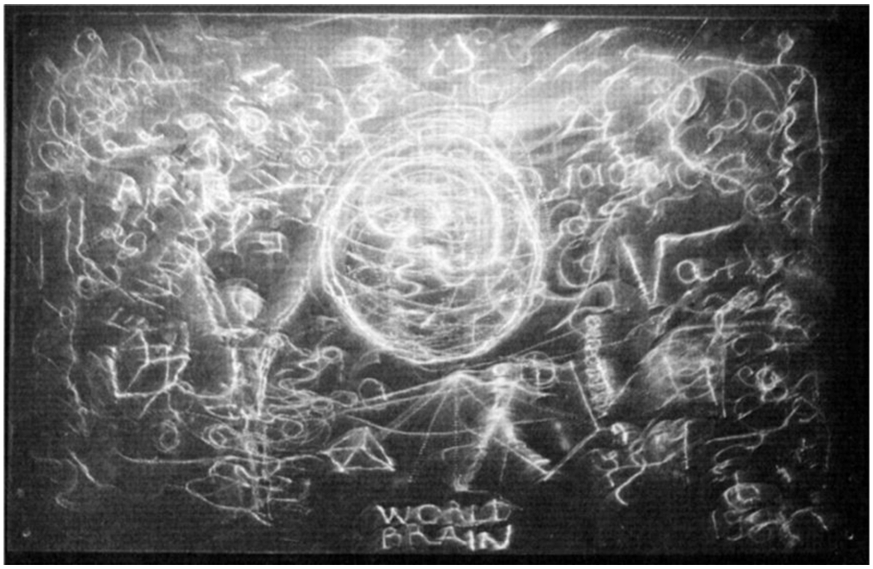


Henri La Fontaine

SLIDE #5 Paul Otlet & Henri La Fontaine

5

Today's Google- and Wikipedia-generation may think that search engines are a new idea but if you examine the history of encyclopedism you find that as early as 1913 Henri La Fontaine, the co-worker of Paul Otlet (the Belgian documentalist) received the Nobel Peace Prize for their efforts to create a centralized font of knowledge and information, accessible to all humanity.



World Brain by Gabriel Lieberman
1980. Engraved aluminum alloy plate. 30” H x 48” W
Chemical Heritage Foundation, Philadelphia

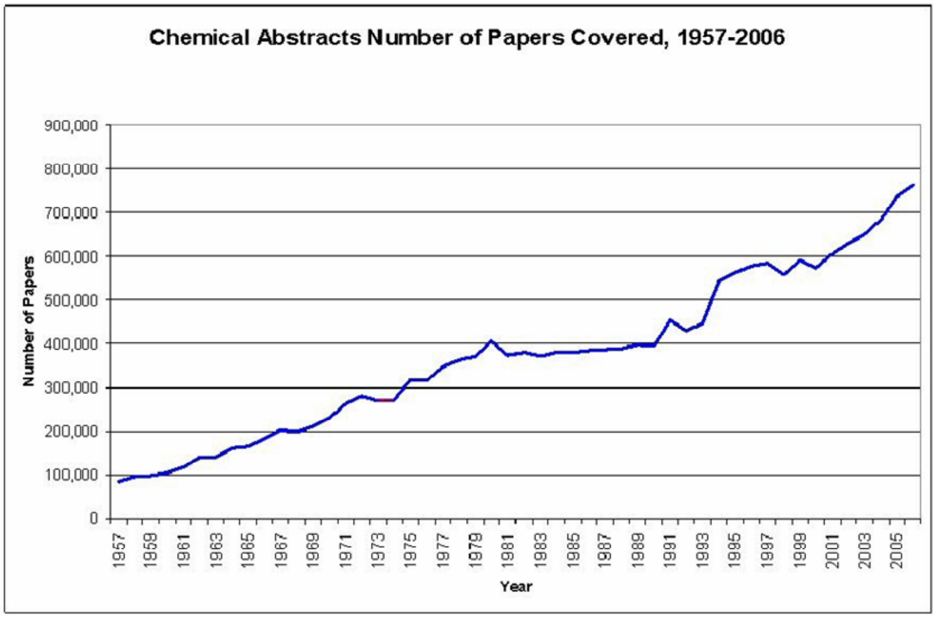
6

SLIDE #6 World Brain Holographic etching

Twenty five years ago, as a testimonial to these pioneering efforts I commissioned the artist-engineer Gabriel Lieberman to create the first holographic etching called the “World Brain”, which can be viewed on the Web and seen in person at the Chemical Heritage Foundation in Philadelphia, a stone’s throw from Independence Hall.[4] (www.garfield.library.upenn.edu/art/isiart/hologram3.jpg)

To establish the impact of scientific information systems on science progress is like trying to separate the proverbial chicken and egg. Ever since the first scientific journals started in 1665 including *Journal des Scavans* in Paris and the *Philosophical Transactions of the Royal Society* in London it has been axiomatic that research is not completed until its results are made accessible to the entire community. That was the premise of the American Philosophical Society when it was founded in Philadelphia in 1745 by Benjamin Franklin among others. Its *Transactions*, started in 1769, is the oldest scholarly journal in America. The exponential growth of the journal literature has been accompanied by enormous growth in the scientific enterprise as described in Derek deSolla Price’s classic works “Science Since Babylon” and “ Little Science, Big Science.”

By the middle of the 19th century, scientists were aware of the need for systems that could make it possible to keep up with the published literature. It was not unusual for scholars to complain that it had become impossible to read everything. That is why abstracting and indexing services came into being, especially in Germany. Every chemist learns the names of Beilstein and Gmelin.



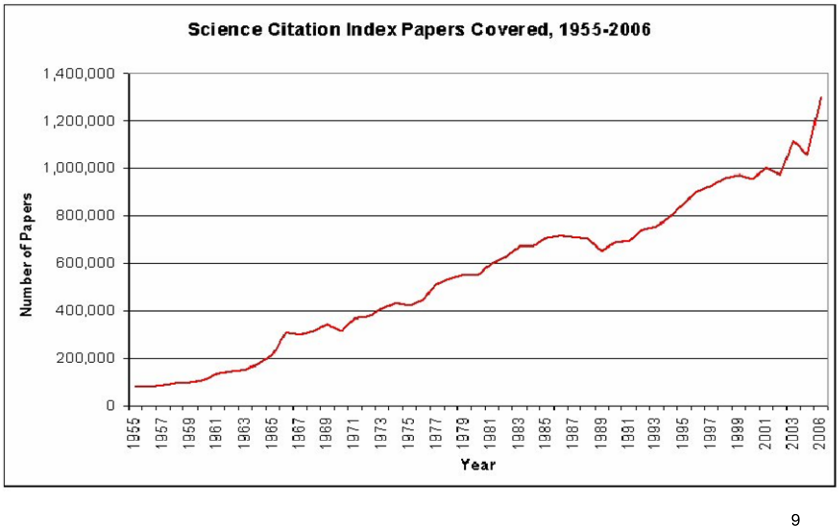
SLIDE #7 Chemical Abstracts Number of Papers Covered 1957-2006

By the beginning of the 20th century, American science had grown to the point where it recognized the need for access to the worldwide patent and journal literature.

Dr. Milton Harris, ACS Board Chairman, Dr. Fred Tate, Assistant Director and Dale Baker, CAS Director (left to right) inspect the IBM 360/40 computer at CAS's Columbus Office.

SLIDE #8 Fred Tate and Dale Baker

Last month, Chemical Abstracts Service celebrated its 100th anniversary.



SLIDE # 9 SCI Papers Covered 1955-2006

As I pointed out on Chemical Heritage day last May in Philadelphia, the growth curve for *Chemical Abstracts* is paralleled by the growth of the *Science Citation Index.*[5] Derek de Solla Price used similar measures to demonstrate the exponential growth of science.

SLIDE #10 Garfield and Price

10

While the scientific and library communities in their typically conservative fashion took more than a few decades to accept the concept of citation searching it is now taken for granted. Indeed the advent of the internet and search engines like Google has increased the awareness of citation linking and ranking. Page ranking is an extension of the journal ranking concept.

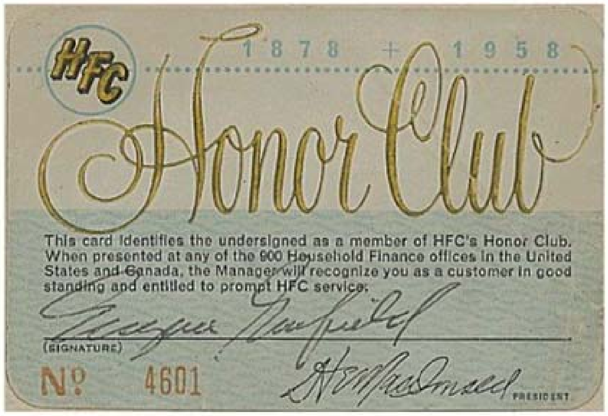
Today we are preoccupied with improving the quality of covert intelligence services in our effort to counteract terrorism. This is a modern repetition of our need to improve and eliminate unecesary duplication in information gathering techniques. Few of you will have forgotten our national shock when Sputnik was launched by the Russians in 1957. Our covert and overt intelligence capabilities were challenged then too. Everyone was studying Russian then. In 1964 I and others testified before Congressional Committees on the need for improving our information activities.[6]

In 1955 I read a paper at the AAAS meeting entitled the "need for a national science intelligence service."[7] While we take for granted today's multi-billion dollar information industry, back in the days of Hubert H. Humphrey's Senate committee and Chicago Congressman Roman Pucinski's House Committee, there was a great clamor about our failing to anticipate and recognize the scientific advances made by the Soviet Union which had established their VINITI in 1958. That same year I gave a paper at the 1958 ICSI conference in Washington on the need for a unified indexing system which might be compared with trying to get the intelligence services to talk to one another.[8]

Eugene Garfield outside the Log Cabin in New Jersey

SLIDE #11 Garfield in front of log cabin

As a personal note let me recall that in 1960 I changed the name of my young consulting company – Eugene Garfield Associates, Information Engineers – to The Institute for Scientific Information.



HFC Card

12

SLIDE #12   HFC Certificate

If you refer to my essay on how it all began with a loan from Household Finance Company you will get an idea of how we financed the enterprise that became the Institute for Scientific Information.[9]

I changed the name for **two reasons**… one was to offset the stigma of operating a private commercial for-profit company which published *Current Contents*.. In those days the bias against private enterprise in the information business was real and tangible. While today the National Federation of Abstracting and Indexing Services (NFAIS) accepts members from both the profit and non-profit world, that was not the case then.


Boris Anzlowar

SLIDE #13   Boris Anzlowar (one of five founders of IIA)

That is why I and four other individuals – Bill Knox, Boris Anzlowar, Saul Herner and Jeff Norton - established the Information Industry Association. IIA is now called the Software and Information Industry Association.

The second reason we changed the name of the company was the fact that the State of Pennsylvania would not allow us to use the term "information engineers" to describe our activities, since I was not a graduate of an engineering school – this in spite of the fact that a few years later I taught a course in information retrieval at the University of Pennsylvania Moore School of Electrical Engineering to graduate engineers.

When I entered the chemical information world, the importance of science information activities was already well recognized in industry.[10] DuPont had its Scientific Intelligence Department. My first consulting client – Smith Kline & French Laboratories– (now Glaxo) had its Scientific Literature Department as did other pharmaceutical companies. It was not uncommon for such departments to command 10% of the total R&D budget. And this was paralleled in the U.K. at companies like Imperial Chemical Industries (ICI), in France at Roussel Uclaf and at Hoechst in Germany. Indeed, the international recognition of the value of scientific information as necessary for sci-tech intelligence was taken for granted.

Information pioneers like Joseph Becker, Librarian of the CIA, were known to all of us in the library and information science world. Indeed the CIA library was the first paid subscriber to the *Science Citation Index*. The second subscriber was the National Library of the Peoples Republic of China in Beijing followed shortly afterwards by the Library of the Soviet Academy of Sciences in Moscow.

As I recently reported in Dublin at a two-day celebration of the Irish- born polymath John Desmond Bernal, essentially the first quantitative studies of science activity began with Bernal's 1939 book "The Social Function of Science". (http://garfield.library.upenn.edu/histcomp/bernal-jd_soc-func-sci/) There were minor uses of bibliometric data reported in the previous decades. However, the "science of science" was initiated by Bernal. The term and discipline became widely recognized as serious science when Derek deSolla Price published his two books, "Science since Babylon" and "Little Science Big Science" in 1961 and 1963. In the years that followed, his descriptions of the exponential growth of science and other quantitative studies became known as "Scientometrics".

While the term "Bibliometrics" was coined by Alan Prichard in 1969[11] it was the Russian polymath V. V. Nalimov who coined the term "Scientometrics" around 1968.

Slide #14 V.V. Nalimov

It is widely recognized that the growth of the field of scientometrics is due to the regular appearance of the *Science Citation Index* in 1964 which ultimately led to the founding of the journal *Scientometrics.*

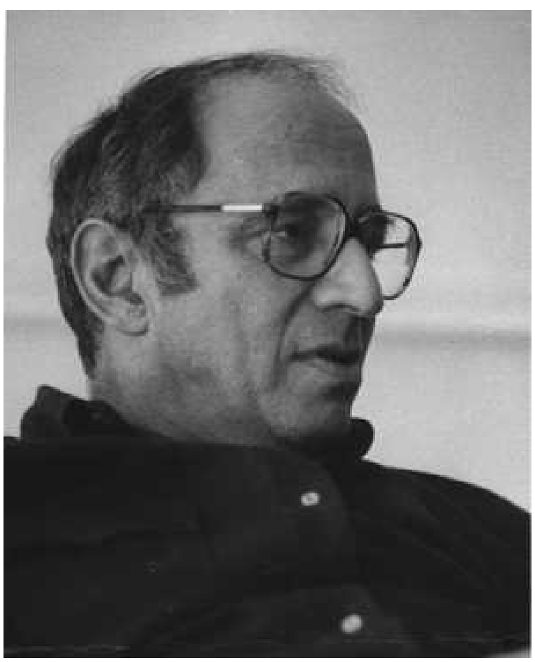
Thanks to the translation of Nalimov's book by the U.S. Government, it was known to a few Western experts but was not widely disseminated. Without the internet, few people knew the work and its historical roots. However, the advent of the journal *Scientometrics* in 1978 formalized the transition from the awkward term "science of science".

SLIDE #15 Bernal

The Society for Social Studies of Science (4S) was established in 1975 and initially it showed an intense interest in quantitative studies and in Scientometrics but that has ceased to be the case.

Thomson ISI remains the sponsor of the 4S Bernal Award whose first few winners included Derek deSolla Price and Robert K. Merton and Thomas Kuhn.

SLIDE #16 Merton, Zuckerman, Garfield

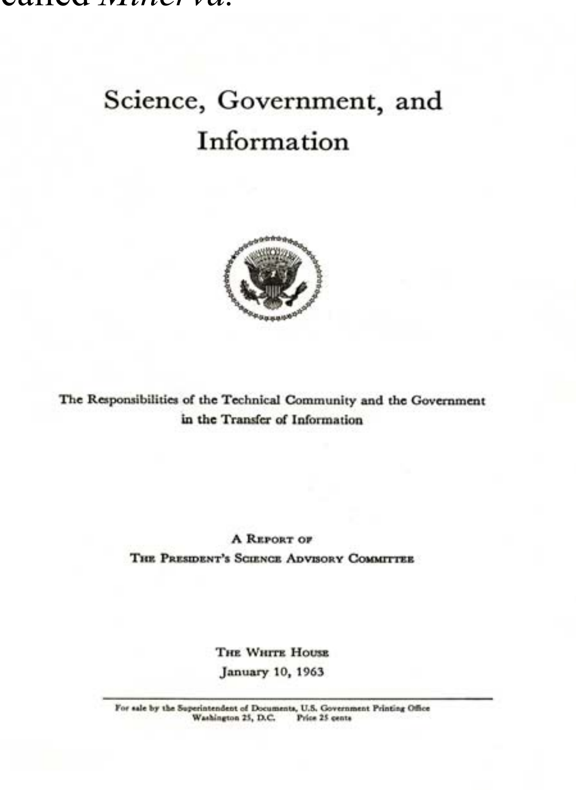


SLIDE # 17 Thomas Kuhn

The advent of *Science Citation Index* in the sixties, of course had a major impact on the growth of scientometrics. Without the *SCI* scholars would not have had the database needed for conducting studies outside the traditional scientific boundaries of chemistry, physics, etc. The unique inclusion of citation linkages in *SCI* made it the major working tool of science policy analysts which facilitated the science indicators movement. The National Science Foundation was quick to recognize that SCI's bibliometric data provided a measurable basis for conducting bi-annual reports on the state of science in the U.S. Norman Hackerman, who died this year at the age of 96 was Chairman of the National Science Board which issued the Science Indicators for 1976. Here is a quote from that report…

"In 1968 the Congress directed the National Science Board to assess the status and health of science, including such matters as national resources and manpower, in reports to be rendered to the President for submission to the Congress. In 1973 the Board initiated the Science Indicators series, and in 1976 a joint committee of the Congress indicated its continuing interest in this particular series. Science Indicators-1976 is the ninth such annual report and the third in the Science Indicators series. With it, the Board continues its effort to describe quantitatively the condition of science and research in the United States."

As an extension of my earlier remarks, I thought it would be of some personal interest to say something about Alvin M. Weinberg, the erstwhile Director of the Oak Ridge National Laboratory. Al Weinberg was Chairman of the President's Science Advisory Committee. PSAC issued the famous Weinberg Report in 1963 entitled "Science, Government and Information." This document originally published by the GPO was reprinted in an early 1963 issue of the then new journal called *Minerva.*[12]



Science, Government, and Information

The Responsibilities of the Technical Community and the Government in the Transfer of Information

A Report of
The President's Science Advisory Committee

The White House
January 10, 1963

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington 25, D.C. Price 25 cents

SLIDE #18 Weinberg Report "Science, Government and Information"

CC/NUMBER 32
AUGUST 12, 1991

This Week's Citation Classic®

Weinberg A M. Criteria for scientific choice. *Minerva* 1:159-71, 1963.
[Oak Ridge National Laboratory, TN]

I suggest a set of criteria according to which the merit of a proposed scientific enterprise might be judged. The criteria are classified as *internal*, arising from within the relevant science, or external, arising from outside the science that is being judged. Internal criteria include competence of the investigators and ripeness of the field for exploitation—i.e., the likelihood that the proposed research will reach its goal. External criteria include relevance to engineering and other applications, relevance to achievement of social goals, and relevance to the basic scientific fields in which the proposed undertaking is embedded. [This paper has been cited in more than 85 publications.]

Origins of Criteria for Scientific Choice

Alvin M. Weinberg
Oak Ridge Associated Universities
P.O. Box 117
Oak Ridge, TN 37831-0117

"Criteria for scientific choice" was first given in 1961 as an invited lecture, entitled "An Agenda for Science," at a meeting of the honorary society Phi Kappa Phi, at the University of Tennessee. The title "Criteria for scientific choice" was suggested to me by Edward Shils, editor of *Minerva*. At the time, I was a member of the President's Science Advisory Committee, as well as director, Oak Ridge National Laboratory. The paper was my attempt to come to grips with the central problem of scientific administration: the allocation of resources among competing scientific claimants, all of whose proposals are meritorious and are, epistemologically speaking, equally true. Thus, "Criteria" attempts to analyze the meaning of "value" in science. Traditionally, the philosophy of science is mostly concerned with epistemology—how do we decide that a given science is "true." Here I propose an "axiology" of science—how do we decide that a given scientific enterprise is valuable, more valuable than a competing scientific enterprise.

The proposed internal and external criteria are, with one exception, hardly original. The exception is my criterion of "scientific" merit. The scientific merit of a piece of basic science is to be judged by the influence that it has and the illumination it sheds on the neighboring fields of science in which it is embedded. This criterion of embeddedness represents an extension to empirical science of John von Neumann's criteria of merit for a purely mathematical discipline—the bearing it has on the surrounding mathematical discipline.[1] I am grateful to my late colleague, Eugene Guth, for calling my attention to von Neumann's idea.

"Criteria" appeared at the time that budgets for science were being increasingly squeezed. Administrators in government were hungry for advice as to how to allocate the scientific pie, and "Criteria" seemed to offer a rationale, if not a recipe, for making such judgments. A sort of cottage industry devoted to criticizing and improving the criteria has since sprung up among policy analysts.[2,3] Perhaps the main influence of "Criteria" was in the National Science Foundation's (NSF) *Information for Reviewers*: The four NSF criteria derive rather directly from the criteria set forth in the original *Minerva* article.

The organization of the scientific enterprise implicit in "Criteria" is a pyramid in which allocations are made at the top by government administrators.[4] In this sense, science is seen as being organized, more or less, by an intrusive government. This "socialist" view of science contrasts with Polanyi's *Republic of Science*, in which the course of science is determined by myriad independent scientific practitioners. The *Republic of Science* is free market and decentralized. My scientific enterprise is much more socialist and centralized. Actually, I would say that where Polanyi's democratic republic is a good model for Little Science, my socialistic republic applies more to Big Science.[5,6]

19

SLIDE #19 Citation Classic "A" Criteria for Scientific Choice

Origins of Criteria for Scientific Choice

Alvin M. Weinberg
Oak Ridge Associated Universities
P.O. Box 117
Oak Ridge, TN 37831-0117

"Criteria for scientific choice" was first given in 1961 as an invited lecture, entitled "An Agenda for Science," at a meeting of the honorary society Phi Kappa Phi, at the University of Tennessee. The title "Criteria for scientific choice" was suggested to me by Edward Shils, editor of *Minerva*. At the time, I was a member of the President's Science Advisory Committee, as well as director, Oak Ridge National Laboratory. The paper was my attempt to come to grips with the central problem of scientific administration: the allocation of resources among competing scientific claimants, all of whose proposals are meritorious and are, epistemologically speaking, equally true. Thus, "Criteria" attempts to analyze the meaning of "value" in science. Traditionally, the philosophy of science is mostly concerned with epistemology—how do we decide that a given science is "true." Here I propose an "axiology" of science—how do we decide that a given scientific enterprise is valuable, more valuable than a competing scientific enterprise.

The proposed internal and external criteria are, with one exception, hardly original. The exception is my criterion of "scientific" merit. The scientific merit of a piece of basic science is to be judged by the influence that it has and the illumination it sheds on the neighboring fields of science in which it is embedded. This criterion of embeddedness represents an extension to empirical science of John von Neumann's criteria of merit for a purely mathematical discipline—the bearing it has on the surrounding mathematical discipline.[1] I am grateful to my late colleague, Eugene Guth, for calling my attention to von Neumann's idea.

"Criteria" appeared at the time that budgets for science were being increasingly squeezed. Administrators in government were hungry for advice as to how to allocate the scientific pie, and "Criteria" seemed to offer a rationale, if not a recipe, for making such judgments. A sort of cottage industry devoted to criticizing and improving the criteria has since sprung up among policy analysts.[2,3] Perhaps the main influence of "Criteria" was in the National Science Foundation's (NSF) *Information for Reviewers*: The four NSF criteria derive rather directly from the criteria set forth in the original *Minerva* article.

SLIDE #20 Citation Classic "A" ENLARGED

In that same journal issue, Dr. Weinberg published his now classic paper on "Criteria for scientific choice" which went on to become a *Citation Classic* – posted at http://citationclassics.org with 4,000 other *Citation Classics Commentaries.*

CC/NUMBER 34
AUGUST 26, 1991

This Week's Citation Classic®

Weinberg A M. Science and trans-science. *Minerva* 10:209-22, 1972.
[Oak Ridge National Laboratory, TN]

Predictions of rare events—for example, the estimate of the number of deleterious biological effects resulting from exposures to environmental insults at dose levels far below the levels at which effect can be seen—lie beyond the power of science. Such questions, which are isomorphic with questions that can be answered by science, are designated as "trans-scientific." Many of the most urgent policy issues, particularly the establishment of regulatory standards for exposure to low-level insult, involve trans-scientific, not scientific, questions. [The *SCI*® and the *SSCI*® indicate that this paper has been cited in more than 105 publications, making it the most-cited article published in this journal.]

Origins of Science and Trans-Science

Alvin M. Weinberg
Medical Sciences Division
Oak Ridge Associated Universities
Oak Ridge, TN 37831-0117

I coined the word "trans-science" at the time Oak Ridge National Laboratory was becoming involved in the debate over nuclear power—in particular the debate over the hazard of low levels of radiation. The public's exaggerated estimate of risk was at the root of the difficulties nuclear energy was facing.[1] If ever there was a trans-science question, this was it.

After the paper was published, Harvey Brooks added another dimension to "trans-science"—the evolution in time of systems governed by large classes of nonlinear equations. Poincaré was one of the first to stress that the ultimate behavior of such systems is sensitive to tiny perturbations in the initial conditions. Chaos is a manifestation of such Poincaré instabilities. Brooks suggested that an analysis of such situations was beyond the power of mathematics, and therefore, was trans-scientific.[2]

The term "trans-science" is used quite widely now. Perhaps most notable was W. Ruckelhaus's admission in 1985 that many of the EPA's regulations hang on the answers to questions that can be asked of science but cannot be answered by science—i.e., are trans-scientific.[3]

In this present Age of Anxiety, we have become a society of very healthy hypochondriacs. Although life expectancy in the West has increased by an astonishing 20 years during the twentieth century, we worry more than ever about small environmental insults that may be carcinogenic. That science cannot shed much light on the biological effects of low-level insult is gradually being recognized in many quarters. For example, W.G. Wagner concludes: "... in order to accommodate trans-science, the judicial framework must change.... Trans-scientific obstacles can be circumvented by referring to more predictable notions of qualitative causation and unreasonable conduct—(thus) the courts may be able to reincorporate the principle of deterrence into the adjudication of toxic torts."[4]

In addition to giving a name to an idea that regulators and toxic torts lawyers had been grappling with, "Science and trans-science" has added another dimension to the perennial quest for limits to science. To the limits of science posed by Heisenberg's uncertainty principle, or the second law of thermodynamics, or, in a different sense, by society's limited ability to support science, we now speak of a "trans-scientific" limit as a distinct philosophic category.

SLIDE #21 Citation Classic "B" – Science and trans science

CC/NUMBER 34
AUGUST 26, 1991

This Week's Citation Classic®

Weinberg A M. Science and trans-science. *Minerva* 10:209-22, 1972.
[Oak Ridge National Laboratory, TN]

Predictions of rare events—for example, the estimate of the number of deleterious biological effects resulting from exposures to environmental insults at dose levels far below the levels at which effect can be seen—lie beyond the power of science. Such questions, which are isomorphic with questions that can be answered by science, are designated as "trans-scientific." Many of the most urgent policy issues, particularly the establishment of regulatory standards for exposure to low-level insult, involve trans-scientific, not scientific, questions. [The *SCI*® and the *SSCI*® indicate that this paper has been cited in more than 105 publications, making it the most-cited article published in this journal.]

Origins of Science and Trans-Science

Alvin M. Weinberg
Medical Sciences Division
Oak Ridge Associated Universities
Oak Ridge, TN 37831-0117

I coined the word "trans-science" at the time Oak Ridge National Laboratory was becoming involved in the debate over nuclear power—in particular the debate over the hazard of low levels of radiation. The public's exaggerated estimate of risk was at the root of the difficulties nuclear energy was facing.[1] If ever there was a trans-science question, this was it.

After the paper was published, Harvey Brooks added another dimension to "trans-science"—the evolution in time of systems governed by large classes of nonlinear equations. Poincaré was one of the first to stress that the ultimate behavior of such systems is sensitive to tiny perturbations in the initial conditions. Chaos is a manifestation of such Poincaré instabilities. Brooks suggested that an analysis of such situations was beyond the power of mathematics, and therefore, was trans-scientific.[2]

The term "trans-science" is used quite widely now. Perhaps most notable was W. Ruckelhaus's admission in 1985 that many of the EPA's regulations hang on the answers to questions that can be asked of science but cannot be answered by science—i.e., are trans-scientific.[3]

In this present Age of Anxiety, we have become a society of very healthy hypochondriacs. Although life expectancy in the West has increased by an astonishing 20 years during the twentieth century, we worry more than ever about small environmental insults that may be carcinogenic. That science cannot shed much light on the biological effects of low-level insult is gradually being recognized in many quarters. For example, W.G. Wagner concludes: "... in order to accommodate trans-science, the judicial framework must change.... Trans-scientific obstacles can be circumvented by referring to more predictable notions of qualitative causation and unreasonable conduct—(thus) the courts may be able to reincorporate the principle of deterrence into the adjudication of toxic torts."[4]

In addition to giving a name to an idea that regulators and toxic torts lawyers had been grappling with, "Science and trans-science" has added another dimension to the perennial quest for limits to science. To the limits of science posed by Heisenberg's uncertainty principle, or the second law of thermodynamics, or, in a different sense, by society's limited ability to support science, we now speak of a "trans-scientific" limit as a distinct philosophic category.

SLIDE #22 Citation Classic "B" ENLARGED

In this slide and the next you see the *Citation Classic* commentary by Dr. Weinberg on his paper "Science and Trans-science" also published in *Minerva* one decade after the previous citation classic. At the time it was the most-cited paper ever published in *Minerva*.

Most Cited Papers in *Minerva*

1. ZUCKERMA.H, MERTON RK
   Patterns Of Evaluation In Science - Institutionalisation, Structure And Functions Of Referee System
   MINERVA 9 (1): 66-100 1971
   Times Cited: 309

2. WEINBERG AM
   → **Science And Trans-Science**
   MINERVA 10 (2): 209-222 1972
   Times Cited: 225

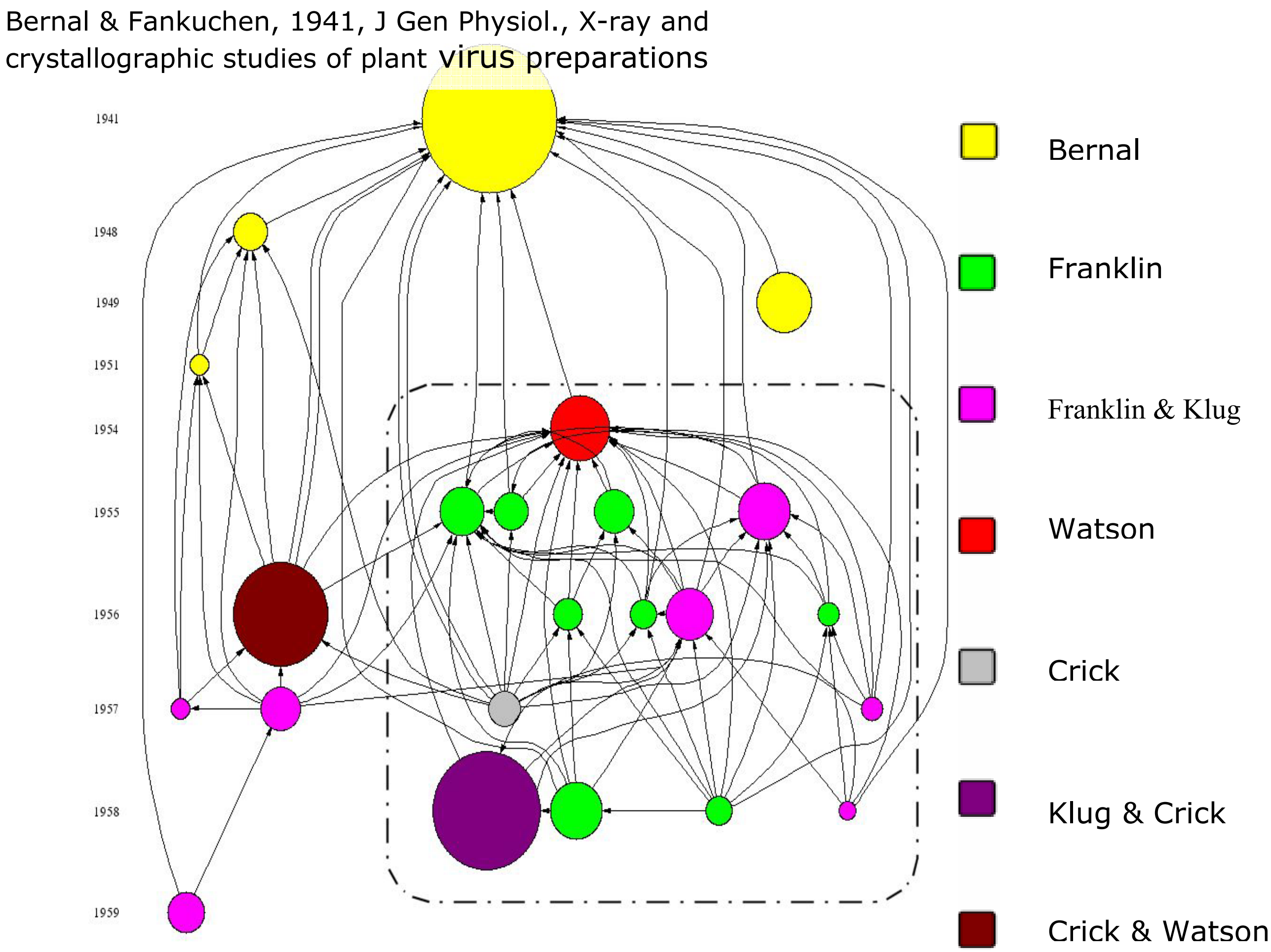
3. POLANYI M
   The Republic Of Science – It's Political And Economic-Theory
   MINERVA 1 (1): 54-73 1962
   Times Cited: 141

4. MULLINS NC
   Development Of A Scientific Specialty - Phage Group And Origins Of Molecular Biology
   MINERVA 10 (1): 51-82 1972
   Times Cited: 107

5. WEINBERG AM
   → **Criteria For Scientific Choice**
   MINERVA 1 (2): 159-171 1963
   Times Cited: 105

SLIDE #23 - Most-cited papers in Minerva

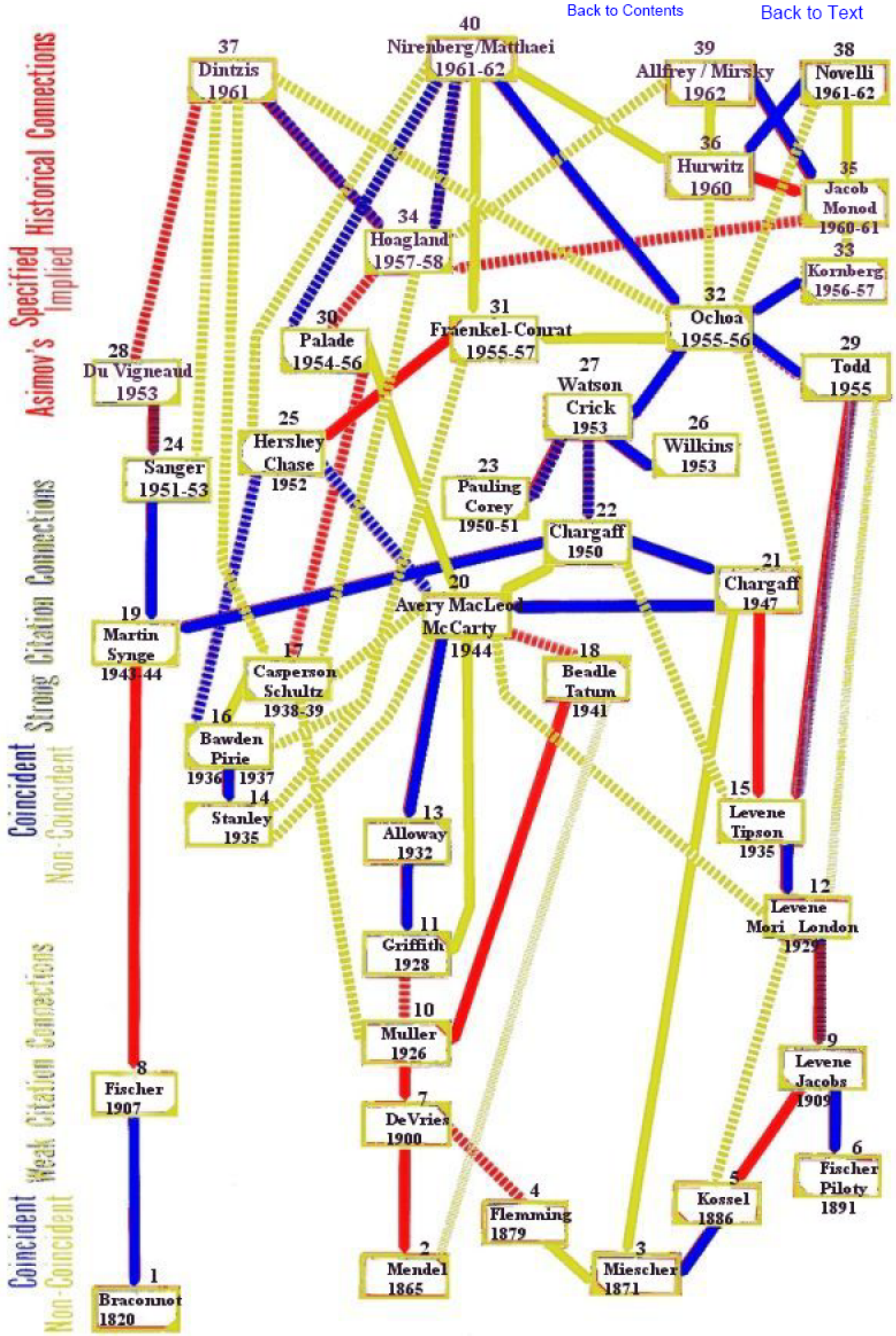
These two classic papers by Weinberg remain in the top 5 papers published in that journal. Reading his comments sixteen years later, one can see that he finally appreciated the difficulty in assigning value in science. It is not a coincidence that his remarks about Polanyi's democratic republic of Little Science stood in contrast to the “socialistic” republic of Big Science. In that sense, Weinberg was implicitly a disciple of J.D. Bernal, the father of the social studies of science.



SLIDE #24 Historiograph showing connections between Bernal and Franklin et al.

I just returned from a Symposium in Dublin, Ireland, celebrating the life of Bernal and used the occasion to show, by visualization techniques, the citational connections between his work in x-ray crystallography and that of his descendents – Rosalind Franklin, Aaron Krug, J.D. Watson, Francis Crick, and Maurice F. Wilkins. The latter three received the Nobel Prize for identifying the Double Helix Structure of DNA. Bernal also produced five other students who won the Nobel prize.

Back to Contents Back to Text



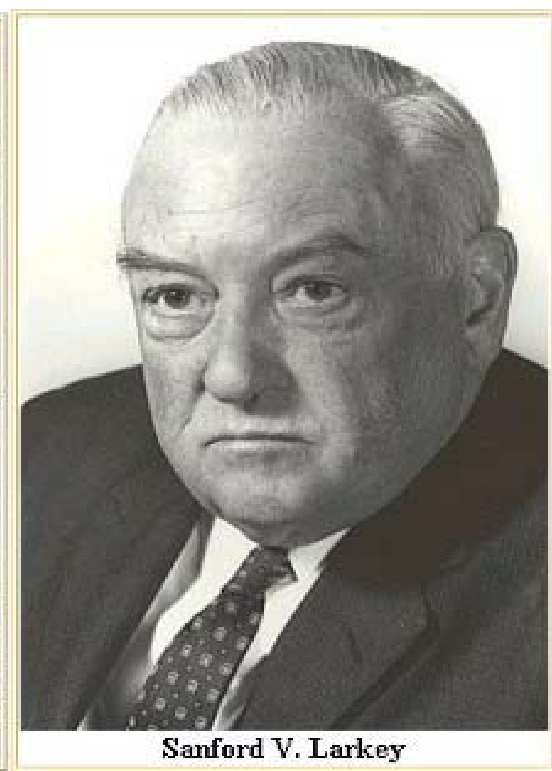
SLIDE #25 DNA OVERLAY – Writing the History of Science through citation analysis

Back in 1964 Dr. Irving Sher and I demonstrated how citation analysis could help trace the evolution of genetics from Mendel to Watson & Crick.[13]

This work eventually led to further work on using data from the Web of Science to create genealogical historiographs of science topics.

To conclude, it would have been fun to trace for you the numerous pioneers in the field of scientific information systems but this series of slides will give you a sampling of some of them beginning with James W. Perry whom I met in 1951 and then running through to Calvin Mooers, the inventor of the term "information retrieval".

SLIDE #26 – 39 INFORMATION PIONEERS – FOLLOW BELOW



Slide #26 – James Perry

Slide #27 – S.V. Larkey

Verner Clapp

Early photo of
John Mauchly

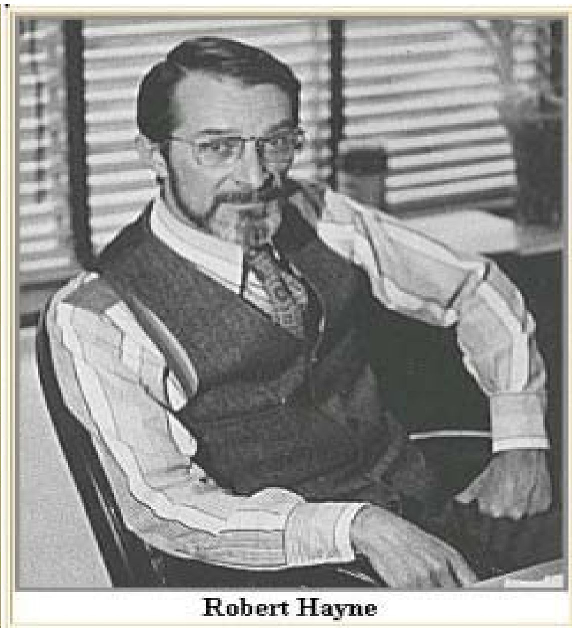
Slide # 28 – Verner Clapp Slide #29 – John Mauchly, co-inventor of the Univac.

Seymour Taine with Beryl Ruff

.

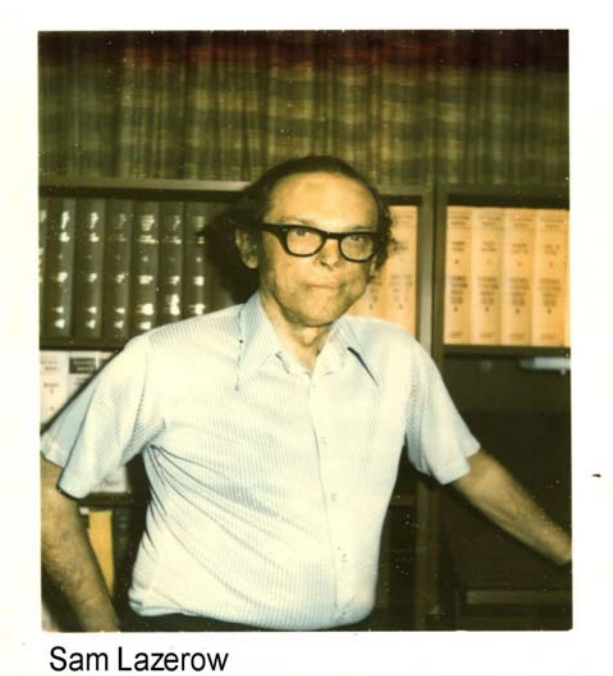
Slide #30 Seymour Taine and Beryl Ruff

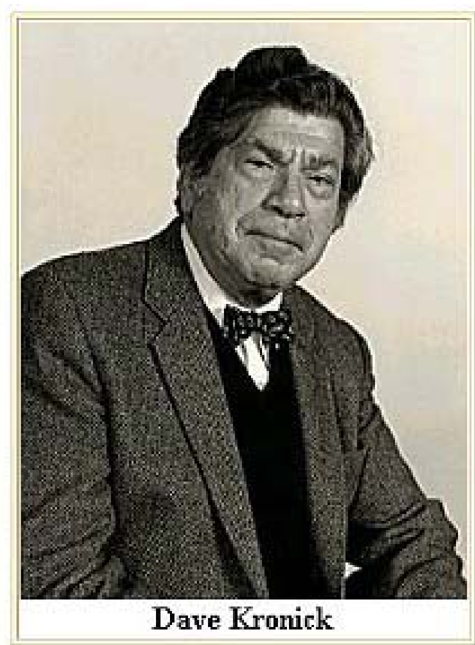
Editor of Index Medicus and Librarian at WHO



Slide # 31 - Medical Historian and Librarian   Slide # 32- Robert Hayne, Associate Editor

Index Medicus





Slide # 33 - Sam Lazerow served at NLM, Library of Congress, and NAL, and the VP of ISI.

Slide # 34 - Dave Kronick was a Medical Historian & Librarian.

Arthur Seidel, Eugene Garfield, Kimber Vought and Irving H. Sher

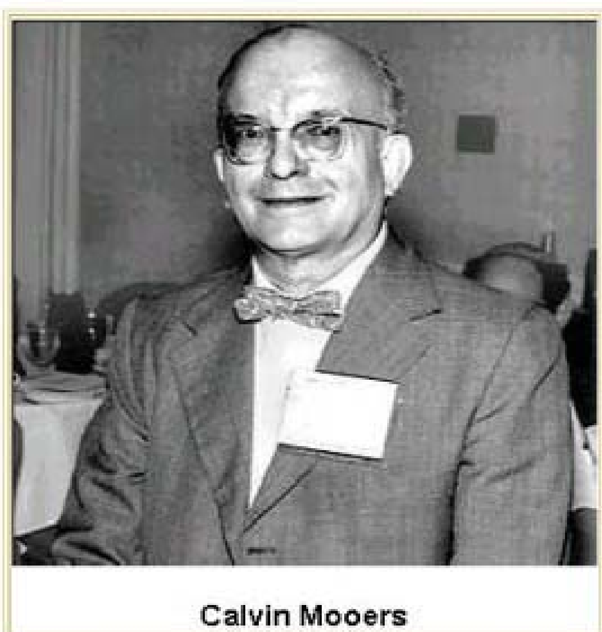
Slide # 35 – A. Seidel, E. Garfield, K. Vought and I.H. Sher

Group including Irving Sher and Arthur Elias with Judy Leondar, Charles Bernier and Bob Maizel

SLIDE #36

Slide # 37 – Henry Small
Co-inventor of Co-citation Analysis

Slide # 38
Former Senior Vice President, ISI



Slide #39 – Calvin Mooers

REFERENCES:

1. back to text "Science, Government, and Information: The responsibilities of the technical community and the government in the transfer of information" *Report of the President's Science Advisory Committee, U.S. Government Printing Office, Washington D.C.* p1-52, January 10, 1963. Members of the Panel on Science Information: W.O. Baker, K. Cohen, J.H. Crawford Jr.,L.P. Hammett, A. Kalitinsky, G.W. King, W.T. Knox, J. Lederberg, M.O. Lee, J.W. Tukey, E.P. Wigner, A.M. Weinberg, J.H. Kelley.

2. back to text Martyn, J. (1964), " Unintentional duplication of research", *New Scientist*, Vol. 21 No.377, pp.338.

3. back to text Wells H.G. "World Brain" New York: Doubleday Doran, 1938.

4. back to text Garfield E. "ISI's "World Brain" by Gabriel Liebermann: The world's first holographic engraving" *Current Contents*, #52, p.5-11, December 28, 1981. Reprinted in *Essays of an Information Scientist*, Vol:5, p.348-354, 1981-82.
http://www.garfield.library.upenn.edu/essays/v5p348y1981-82.pdf

5. back to text Garfield E. "Charting the growth of science" Presented at the Chemical Heritage Foundation on being awarded the Richard J. Bolte, Sr. Award for Supporting Industries, Philadelphia, May 17 2007. Also see Heritage Day Honors, *CEN*, p.36-37, July 16, 2007.
http://garfield.library.upenn.edu/papers/chartinggrowthofscience2007.pdf
http://garfield.library.upenn.edu/papers/chfaward2007.pdf

6. back to text Garfield, E.. "Statement Before the Ad Hoc Subcommittee of the Committee on Education and Labor, House of Representatives, Roman Pucinski, Chair, Eighty-Eighth Congress, First Session, on HR 1946 Part 2." National Information Center. Hearings on a National Research Data Processing and Information Retrieval Center, July 18-19, 1963, Washington, D.C. : US GPO, p. 227-52.
http://garfield.library.upenn.edu/papers/egtestimony1963.pdf

7. back to text Garfield, E. & Hayne, R."Needed - A National Science Intelligence and Documentation Center ," p.1-7, 1955. Presented at the "Symposium on storage and retrieval of scientific information". Annual meeting of the American Association for the Advancement of Science (AAAS), December 28, 1955, Atlanta, GA. (Definition of Documentation).
http://www.garfield.library.upenn.edu/papers/natlsciinteldoccenter.html

8. back to text Garfield, E. "A Unified Index to Science," *Proceedings of the International Conference on Scientific Information. 1958. Washington, D.C.*: National Academy of Sciences - National Research Council, 1, p.461-74, 1959. Conference Proceedings
Reprinted in *Current Contents,* #52, p.5-6, December 27, 1976 and
Essays of an Information Scientist, Vol:2, p.672-673, 1974-76
http://www.garfield.library.upenn.edu/essays/v2p672y1974-76.pdf

9. back to text Garfield, E. "How it all began – with a loan from HFC," *Current Contents*, #3, p.5-8, January 21, 1980. Reprinted in *Essays of an Information Scientist*, Vol:4, p.359-362, 1979-80.
http://garfield.library.upenn.edu/essays/v4p359y1979-80.pdf

10. back to text Weil, B. (1980), "Benefits from research use of the published literature at the EXXON Research Centre, New Jersey", *Special Librarianship: A New Reader*, Scarecrow Press, Metuchen, NJ, pp.586-94.

11. back to text Prichard A. “Statistical bibliography of bibliometrics” *Journal of Documentation* 25(4):348-&, December 1969

12. back to text “Science, government and information :The responsibilities of the technical community and the government in the transfer of information” Report of the President’s Science Advisory Committee (Washington:U.S. Government Printing Office, 1963) *Minerva* Volume 2(1): 91-117, September, 1963. DOI. 10.1007/BF01100783

13. back to text Garfield E, Sher IH, Torpie RJ, "Use of citation data in writing the history of science" December 31, 1964. ISI Philadelphia PA. 19104. http://www.garfield.library.upenn.edu/papers/useofcitdatawritinghistofsci.pdf