THE EFFECTIVENESS OF THE PRACTICE OF CORRECTION AND REPUBLICATION – A BIBLIOMETRIC ANALYSIS

A Dissertation
Presented to
The Faculty of the Graduate School
University of Missouri-Columbia

In Partial Fulfillment
of the Requirements for the Degree

Doctor of Philosophy

By
GABRIEL MINER PETERSON

Dr. MaryEllen C. Sievert, Dissertation Supervisor

DECEMBER 2006

The undersigned, appointed by the Dean of the Graduate School, have examined the dissertation entitled

THE EFFECTIVENESS OF THE PRACTICE OF CORRECTION AND REPUBLICATION ON THE BIOMEDICAL LITERATURE – A BIBLIOMETRIC ANALYSIS

Presented by Gabriel M. Peterson

a candidate for the degree of Doctor of Philosophy

and hereby certify that in their opinion it is worthy of acceptance

_____

Professor MaryEllen Sievert

_____

Professor John Weman

_____

Professor James Laffey

_____

Professor Sanda Erdelez

_____

Professor George Demiris

Dedication

To all of my teachers.

With special thanks to my grandfather LCL Browne and love to my wife, Sandy.

ACKNOWLEDGEMENTS

I would like to thank the National Library of Medicine for their support in the form of a training and research fellowship.

I would particularly like to thank my advisor and mentor Dr. MaryEllen Sievert for her steadfast support and enthusiasm.

TABLE OF CONTENTS

APPENDICES

LIST OF FIGURES

FIGURE

LIST OF TABLES

TABLE

THE EFFECT OF CORRECTION AND REPUBLICATION OF THE BIOMEDICAL LITERATURE – A BIBLIOMETRIC ANALYSIS

Gabriel Peterson
Dr. MaryEllen Sievert, Dissertation Supervisor

ABSTRACT

This research is a bibliometric study that measures incidence of citation of the flawed and corrected versions of scholarly articles. If the practice of correction and republication is effective, then the incidence of citation of the flawed version should diminish, and increased incidence of citation of the republication should be observed. If there is no difference between citation levels for corrected and republished versions of articles (or if citation of the flawed originals is higher than that of the corrected versions), then correction and republication is not effective at preventing the citation of flawed publications that have been officially withdrawn by their authors or publishers. A statistically significant difference between citation levels of flawed originals and corrected republications is not detected until 8-12 years post-republication. Results showed substantial variability among sources in their provision of authoritative bibliographic information. The assertion that inappropriate citation behavior may be partly attributable to author ignorance is not refuted by the data.

This study demonstrates that the practice of correction and republication is only marginally effective. The research shows that the practice of correction and republication does not prevent the continued citation of flawed articles post-correction, detecting only a slight decrease in the citation of flawed articles after publication of the corrected version. It is possible that the practice would be made more effective if prominent sources of bibliographic information were more consistent in providing users with information about the status of anomalous articles and the existence of post-publication modifications to the literature. It is certainly incumbent upon the scientific community to improve the effectiveness of making searchers aware of post-publication changes to the literature in order to prevent the potentially tragic consequences of application of flawed information by scientists and medical professionals. Failure to do so will undoubtedly result in a reduction of public trust in the reliability scientific literature and its users.

The effect of correction and republication of the biomedical literature – A bibliometric analysis

Chapter 1: The problem and its context

The biblioremeditative practice of correction and republication has resulted in the accumulation of a body of nearly identical pairs of articles, in each case one member of the pair containing erroneous information. This is a study of documents that have been formally withdrawn and corrected and of their counterparts and replacements, the republished versions. In this study, the uncorrected, flawed version of a published scholarly article is referred to as the "original", which is withdrawn by its authors or publisher in lieu of the "republication" or "republished version".

The purpose of this study is to evaluate the effectiveness of the phenomenon of correction and republication in the biomedical literature. The evaluation of the effectiveness of corrections to the scientific literature is significant because application of flawed biomedical research findings can have significant negative health, scientific and economic consequences. Though the social process of science tends to elevate exemplary work and ignore inferior

work, it is known that flawed literature is sometimes used as the basis of research, and many examples exist of erroneous information making its way into print and being propagated in the literature. Incorrect ideas or results may be published, fraudulent research may be accepted as legitimate, and authors, editors and publishers are all capable of making errors. Though the science tends to be self-correcting, the capacity of researchers to be able to identify faulty information is limited. This inability to readily perceive errors combined with the sheer quantity of information available to the researcher would make the scientific literature unreliable were it not for tools to help manage it. One of the ways that information management tools can assist users is by alerting them to the status of flaws in the literature. In this way, the task of identifying the small number of flawed documents from the multitude of scholarly works is made easier.

This research is a bibliometric study that measures incidence of citation of the flawed and corrected versions of scholarly articles. If the practice of correction and republication is effective, then the incidence of citation of the flawed version should diminish, and increased incidence of citation of the republication should be observed. If there is no difference between citation levels for corrected and republished versions of articles (or if citation of the flawed originals is higher than that of the corrected versions), then correction and republication is not effective at preventing the citation of flawed publications that have been officially withdrawn by their authors or publishers. The study then

examines the degree to which two prominent sources of biomedical bibliographic information (Medline and Web of Science) provide users with information about republications. By measuring the frequency with which databases direct users to accurate versions of scholarly works this study determines whether continued erroneous citation can be attributed to a failure on the part of the providers of bibliographic data to provide researchers with the most reliable source material.

Publication of research findings is the primary means by which scholars communicate professionally. Scholarly publication is an extremely versatile method of communication and is used to perform many tasks and to carry many kinds of information. Some of these functions are performed at the level of individual documents and others rely on the features of the literature as a collective body.

Just as a living body is made up of individual cells, so the body of scientific literature is made up of constituent documents. To extend the anatomical metaphor, as a pathologist may study structures and tissues of a body by examining particular cells, an informetrician may study the body of scientific literature by examining related articles among the multitude of documents. The literature and the documents that constitute it have numerous useful properties, (from an informetric point of view), which are considered at the scale of the individual document and at that of the literature as a body of scholarly work in this chapter. The structure, function and characteristics of the literature are

discussed, particularly with regard to the derivative nature of science and its self-correcting characteristics. Methods for managing and maintaining the integrity of the literature exist, including the practice of correcting erroneous literature. This study is an evaluation of the effectiveness of the practice of correction and republication at replacing one document with a corrected version and is based in part on of previous studies of biblioremediative measures, particularly those evaluating the effectiveness of retraction by examining citation levels. As a pathologist may track the effectiveness of medicine by studying its effects on abnormal tissue, so shall this study track the effectiveness of a treatment designed to remedy flawed literature.

Part 1 – Scholarly communication

Structure – Articles

Because articles are used to communicate manifold, nuanced information, they tend to be formal, highly structured documents. Typically written in an impersonal style, scientific journal publications tend to have a similar structure: A title and author list is followed by an abstract, a short statement briefly describing the purpose and results of the research. Following this, the author provides an introduction to the research describing the context and theoretical foundations of

the research, frequently justifying both by referencing influential previous works. Following this apologia, a description of methods of data collection and analysis and a presentation of results, again possibly with references to other documents to describe or justify methods. The paper's text concludes with an analysis of results and their implications for further study. The article's text is then followed by a list of bibliographic entries for documents referenced in the body of the document. This list of cited documents is known as the bibliography and is the source of data for many informetric studies, including those relying on the technique of citation analysis.

Researchers publish scholarly documents as evidence of scientific endeavor, describing research and findings. Scholarly communications, especially articles published in scholarly journals, present research in part by describing the work in terms of preceding knowledge and inquiry. Formal recognition of antecedent work is made by identifying related documents in the text of the article in a practice known as citation. Citations are text notations that provide the reader with bibliographic information about a document being referenced. Citations link individual documents, ideas and authors over time and distance, thematically applying structure to the multitude of producers, concepts and artifacts of scholarly effort.

Structure – The Literature

A multitude of documents collectively comprise the scientific literature – the body of interconnected published scientific communications. The literature is made up of articles that are related by virtue of the links made by citation. These connections can be used as the basis of mathematical and statistical analysis of the literature. The study and exploitation of these links is sometimes known as citationology. Citationology has numerous applications, among which are the evaluation of relatedness based on incidence of common document citation and analysis of article use and prominence. This latter practice is known as citation analysis and more about this important tool for analyzing scholarly communication is said shortly.

Function - Articles

Authors produce articles and other documents as evidence of their efforts. These articles are published so that a researcher's peers can be informed of the findings. Researchers have two basic motivations to share their results with their contemporaries: first, scientists rely on peers to confirm findings and results. This fundamental mechanism by which science moves forward is discussed in more detail in Chapter 2. Secondly, publication is the benchmark of academic achievement: priority of discovery is traditionally attributed to the first author to publish and publication & subsequent citation are therefore measures by which the eminence of researchers is gauged. Individual articles are thus both media by

which researchers share ideas and discoveries and serve an economic function as tokens of professional accomplishment for their authors.

Function - The Literature

The long-standing scholarly tradition of sharing research findings through publication has produced a massive archive of documents. This collection of documents is used by the scientific community for functions similar to the uses to which individual items are put, insofar as they have both communicative and economic roles.

Scientists publish documents to communicate with their peers and posterity, describing and justifying their work by comparing it to and integrating it with previous work. Though an article stands alone in proclaiming scientific achievement, it is part of a larger body of work to which it is attached by conceptual and literary links. Publication is a form of dialog; in addition to being a soliloquy of achievement, authors use publication to communicate their own results and to discuss the results and conclusions of others. An article and the documents it references are elements in a network through which authors communicate about their studies and engage in the process of debate and consensus building that is the basis of scientific progress. Thus the accumulated literature functions as a basis and defining context for subsequent intellectual efforts.

Scientists claim priority of discovery by achieving the distinction of being the first to publish a discovery, a mark of professional achievement and eminence. Individual documents are bound together by an integument of internal literary references of citations through which an author references contributing or influential works to explain or justify his own assertions or conclusions. In this way, authors can also acknowledge priority of discovery or insight to the appropriate sources, or acknowledge inspiration or intellectual debts. A document may be heavily cited if it is novel, highly influential or noteworthy for some other reason, e.g. a highly publicized exposure of scientific misconduct. Works that are frequently cited are often considered to be significant contributors to science and the authors of those documents reap the reward of commensurate prestige and eminence.

Characteristics of the Literature

Large

Scientists have been publicly sharing their work with peers in the form of publication since the 17th century. (Prior to this time, researchers did share work, but they did not do so in an organized or public way. For more on this topic, see Kronick (Kronick 1976)). Price likens the growth of the scientific literature to the growth associated with the compounding of interest. However with science, unlike finance, there is no withdrawal, leading to a rate of exponential growth.

Price notes a doubling of the literature every 10-15 years, an order of magnitude of growth every 35-50 years. (Price, in Warren (Warren 1981)) The mass of documents that has accrued since the practice began now numbers tens of millions of documents and embodies the formal, official history of scientific inquiry since the practice began. As such, the literature is an archive for science and a researcher can follow the development of a discipline through its literature by iteratively using citations to identify antecedent works. This historiographical analysis of the scientific literature is another application of the technique known as citation analysis.

Derivative

As has already been discussed, scientists rely on the output and consensus of previous researchers as the foundation and justification of their inquiry. Scientists describe the current state of knowledge in terms of previous work, reference methods in terms of examples of the application of the method in other studies, or refer to the analysis or interpretation of other authors. The individual documents that compose the literature collectively describe what is known about a field, the limits of understanding in that domain, and accepted methodologies for performing research. Science is inherently derivative; all scientific inquiry is based on preceding work in its attempt to extend understanding, relying absolutely on the efforts of contemporaries and earlier

researchers for inspiration and direction. It is the dependence of scientists on previous research that makes the integrity of the literature so vital.

Durable

Another notable attribute of scientific output is its longevity. The practice of publication permanently enshrines the work of authors. This is particularly the case with influential works, which may continue to be used and referenced by authors long (even centuries) after the article was published. The longevity of scientific literature has numerous ramifications, particularly the fact that scientific knowledge tends to accumulate, producing a massive collection of documents. Because of this, a single article may become lost in the vast sea of documents, or a piece of bad information may be inadvertently enshrined. This aspect of the literature might be an impediment were it not for the fact that due to citation the literature tends to order itself into a larger, structured collection, rather than a random assortment of documents and thanks to this attribute, literature management tools can be constructed.

The aforementioned longevity of a document is not guaranteed. In order for a document to remain prominent in the literature for a long period of time, it must be highly influential and therefore have some particularly useful or persuasive characteristic. Further, this effect is tempered by the phenomenon known as oblivion thorough incorporation. Oblivion though incorporation is the name given to the tendency for citation of articles to diminish as later authors cite

significant derivative works rather than historically significant other works. (For example, when publishing research, few molecular biologists cite Mendel's 1865 publication describing experiments in plant hybridization or Watson and Crick's 1953 description of the chemical structure of the DNA molecule. (Mendel 1865; Watson and Crick 1953)) Work that cannot be replicated or substantiated, inferior methods or analysis, or other negative characteristics may prevent an article from being highly cited and thus doom it to oblivion through obscurity. Conversely, a researcher should be able to identify highly significant elements in the literature by identifying highly cited articles. Thus, the research community tends to enshrine exemplary work and neglect inferior work; in this way, science tends to be self-correcting.

Self-correcting

Scientists found original research on the results of earlier investigators. The practice of science is to develop consensus regarding explanations for observed phenomena. New knowledge is developed by developing research questions based on the limits of what is known about a subject, then positing and testing explanations, the quality of which are evaluated by other researchers. If the scientific community reaches the conclusion that the presented results in some way extend understanding in their field, the work is incorporated into the knowledge base and is used as the basis of further inquiry. Science is a process of building consensus regarding the best explanation for a phenomenon; by determining what is the most reliable and persuasive explanation for a

phenomenon and developing new understanding based on that knowledge, science tends to codify reliable, useful information and to discount inferior information and analysis: thus, it tends to be self-correcting.

Contains Flaws

Though the social process of science tends to elevate exemplary work and ignore inferior work, it is known that flawed literature is sometimes used as the basis of research. Though the problem is not epidemic, many examples exist of erroneous information making its way into print and being propagated in the literature. Incorrect ideas or results may be published, fraudulent research may be passed off as legitimate, and authors, editors and publishers are all capable of making errors. Whitely demonstrated that scientists generally cannot differentiate between reliable and erroneous literature after such work has passed editorial review. Thus, while the nature of science tends to be self-correcting, the capacity of researchers to be able to identify faulty information is limited. This inability to readily perceive errors combined with the sheer quantity of information available to the researcher would make the scientific literature unreliable were it not for tools to help manage it. One of the ways that information management tools can assist users is by alerting them to the status of flaws in the literature. In this way, the task of identifying the small number of flawed documents from the multitude of scholarly works is made easier. The effectiveness of prominent

sources of biomedical bibliographic information at the task of alerting users is evaluated in this study.

Summary:

Science is a fundamentally communicative process by which researchers collaborate to develop consensus regarding explanations of natural phenomena. The primary mechanism of communication is the publication of formal description and analysis of research findings. This practice of publication serves crucial communicative and socioeconomic roles in the community of science. The practice of formal scholarly communication has resulted in the accumulation of a massive body of literature that represents the history and archive of all scientific knowledge upon which all subsequent research is based. Researchers contextualize their work in terms of this foundation and archive of knowledge by referencing influential works in their own publications through the act of citation. The links established between documents by citation contribute an element of cohesion to the literature, transforming the literature from a massive collection of text to a thematically organized body of information from which researchers can both trace the development of an idea or method and derive new knowledge.

The exponential growth of the literature has necessitated the development of knowledge management tools; leading to the development of numerous technologies, from the encyclopedia in the 17th century to the most recent

technologies, electronic bibliographic databases. These systems not only help users retrieve relevant literature from the archives of science, they can assist in the maintenance of the integrity of the scientific record by alerting users to the existence of flaws and modifications to the literature. If they are successful at this task, little citation of flawed documents should be observed after the correction has been published.

Chapter 1: Part 2- Managing the literature

Indexes

In his description of the development of the scientific literature, Price noted the periodic incidence of “organizational hiatus” through history as scholars developed ways to condense and manage the ever-growing literature. This quest for data compression has fostered the invention of the encyclopedia, the journal of abstracts and the bibliographic index. In the same 1983 essay, Price noted that a similar feat of reorganization had recently been underway as the scientific community developed electronic information management resources. In the intervening 20 years, these resources have largely taken the form of databases or electronic indexes of the literature.

Indexes are guides to records; they do not directly deliver the sought information, but employ a set of tags or descriptors which identify and point the user to the desired information. In the case of journal literature, these tags and descriptors frequently provide the user with bibliographic information about the desired documents; systems employing such a system are known as bibliographic indexes. Indexes are information retrieval tools; they are evaluated by how effective they are at providing the user with their desiderata. These desirable traits may include precision or recall, depending on whether the user is looking for specific data or more general information. The advent of electronic information handling systems has greatly helped in the management and

retrieval of the scientific literature. Indeed, most indexes now exist in an electronic form, the superiority of the technology clearly demonstrated in enhanced search and retrieval compared to the use of printed indexes. Of particular interest to this study are indexes whose purpose is the management and retrieval of biomedical journal literature, particularly the bibliographic index and the citation index.

Citation Indexes

A citation index is a list of bibliographic entries for articles with a sub-list for each entry identifying articles that cite the subject of the entry. Though the citation index is not a new idea, (the legal index Shepard's *Citations* dates to the 1870's and Weinberg reported the use of citation indexes by Talmudic scholars as early as the 12th century), citation indexes did not come to prominence in the scientific community until after the second World War. Rather than relying on the subjectivity of indexers to choose identifiers such as subject, title or author to create bibliographic entries, citation indexes exploit the structural elements of and between documents, operating on the assumption that a relationship to another work is implied by citation. Thus, identifying an article in a citation index will direct the user to all documents that have referenced that article since it was originally published. This structure allows the user to move forward in time in the literature relative to the date the article was published, allowing users to find the most recent articles on a subject. Citation indexes work on the basic assumption of a conceptual relationship in that the citing and cited articles are in some way related and that the cited article is in some way relevant to that doing the citing. Some critics justifiably question the assumption that citers cite positively, competently and appropriately, none of which are universally assured. However, experience has validated the utility of citation indexes and the reliability of the underlying assumptions have been demonstrated, not least by the successful application of citation analysis in identifying of a number of future Nobel laureates.

The relationship implied by citation can be used to perform a variety of illuminating quantitative analyses on the accrued scientific literature. The quantitative analysis of the relationships between citing and cited documents is known as citationology, a method of analyzing the literature that is discussed in considerable detail in Chapter 2.

Bibliographic Indexes

Bibliographic indexes are lists of documents, arranged based on a variety of characteristics, including a hierarchical taxonomic list of descriptors. This kind of index requires a previously arranged scheme for arranging concepts and a secondary file to assist the user in identifying the appropriate records in the hierarchical tree. This second file is typically an ordered list of documents, so a user may systematically pluck salient documents from the hierarchical tree. This secondary list (or lists) may be another index list, possibly containing selected bibliographic information, allowing the user to retrieve information broadly by subject or specifically based on a different identifier, such as date or author name. Such indexes are useful for retrieving general information or specific documents. Further, by examining the bibliographies of those documents the user can study the antecedents of the article and track the development of the discipline but a bibliographic index provides no information about how the paper has been used subsequent to publication.

Indexers - Organizations

At this time in the USA, there exist one particularly prominent publicly available free index of biomedical literature and one major citation index (which is available to the public for a fee), known as Medline and the Science Citation Index, respectively. The organizations that produce and maintain these tools exist to help professionals in gathering information. Because each of these systems plays a key role in this study, each are briefly discussed.

The Institute for Scientific Information

The producer of the most prominent citation index of scientific literature is the Institute for Scientific Information of Philadelphia, PA, (often known by its acronym, ISI). ISI publishes a searchable index that uses citations to an article as index terms known as the Science Citation Index (SCI). Inspired by the handbook of judicial citations of legal precedent first published in the 1873 *Shepard's Index*, the SCI is a tool that enables a user to identify publications that cite earlier work, allowing the user to search the literature forward in time. Prior to this innovation, scholars were limited to examining bibliographies for antecedent works. The ISI currently hosts the largest repository of citation indexes in the world and is a major source of bibliographic information for scholars in many scientific disciplines.

The basis of this indexing strategy is the assumption that by citing a document, the citer is making a statement of relatedness and therefore relevance

about that document. This act of referencing creates a link between the documents, the evidence of which is the bibliographic information in the citing work. By treating these text notations as proxies for the relationship between documents, scientists have been able to quantitatively study aspects of the literature. This practice is called citation analysis, which is defined as an analytical tool which uses reference citations of scientific papers. Citation indexes have been used for a number of kinds of analysis of the literature by the scientific community. Egghe and Rousseau (Egghe and Rousseau 1990) discuss three basic applications for citation analysis: “qualitative and quantitative evaluation of scientists, publications and scientific institutions; modeling of the historical development of science and information search and retrieval.”

The National Library of Medicine

Established in 1836, the Library of the Office of the Surgeon General of the Army was organized into a national resource of biomedical literature by John Shaw Billings, who oversaw its 1865-1895 expansion from an 1800 volume collection to one with 117,000 books and 192,000 pamphlets. Since then, the subsequently renamed National Library of Medicine (NLM) has grown into the largest repository of health and biomedical literature in the world, moving from an originally modest collection of medical pamphlets housed in Ford’s Theater to the modern data storage and serving facility in Bethesda, MD. (NLM)

The National Library of Medicine exists to assist the advancement of science by collecting and disseminating information in the areas of medicine and bioscience. It does so in part by publishing (in print and electronically) guides to health science information in the form of catalogs, bibliographies, indexes and online databases. It also does so by developing resources for recording, storing, retrieving, preserving and communicating health information and by developing tools for associated disciplines such as molecular biology and toxicology. (Source: NLM Functional Statement (NLM)) The National Library of Medicine is now the repository of the largest collection of biomedical literature on Earth, the Medline database. Medline is a 15-million entry bibliographic database available to the public via the Internet (http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?db=PubMed)

The NLM indexes documents based on many attributes, including publication type. The indexing strategy for the NLM includes numerous standard publication types, (article, review, festschrift)and some special designations to identify anomalous publications. The NLM has introduced the special publication types over time, beginning in 1984 with the designation of the special document type “retracted publication” and its complement “retraction of publication”, the latter being an official statement of retraction and providing the bibliographic information for the former. Since then, the NLM has introduced other anomalous publication types, including errata in 1987 and correction and republication of articles in 1991 and provides index tags for these as well.

(More information on this subject can be found at the NLM website devoted to this topic. (NLM))

Anomalous literature & corrective measures

The purpose of bibliographic information sources like Medline is to provide literature and information to assist researchers. In addition to indexing literature in the areas of biomedicine for information retrieval, Medline has undertaken the task of alerting users when post-publication changes must be made to the literature. As was briefly mentioned earlier, it is known that flawed material is occasionally published, integrated into the scientific literature and subsequently cited. Further, it is known that while researchers cannot readily distinguish between flawed and reliable published documents, they do reduce their use of retracted articles (as measured by post-retraction citation) after the retractions are made public. In Whitely's (Whitely, Rennie et al. 1994) study of retracted publications, making users aware of the status of a document was shown to be the key to reducing citation of retracted articles.

NLM identifies a variety of articles that for various reasons, (including error on the part of the authors or publishers, malfeasance and duplication of articles), have been formally withdrawn from the official scientific record. The withdrawal or invalidation of an article by its creators, (authors or publishers), does not involve physically expurgating the documents from libraries, (an act of vandalism anathema to the librarian's ethos!), relying instead upon publication of a formal

notice identifying and providing bibliographic data about the disavowed document and a statement of repudiation. While preserving the historical integrity of the scientific archive, this technique has the significant drawback of being an inefficient way of alerting the public to the fact that a given article has been withdrawn. One of the ways in which NLM assists users is addition of subsequent notices of errata, retractions, corrections & republications, duplicate publications and comments to citations of articles indexed in the Medline database. Users who search Medline are informed if they retrieve a document that qualifies as any of the aforementioned publication types. Thus, NLM endeavors to assist users by using electronic literature management tools to alert users to the status of anomalous articles instead of relying on mere printed alerts. Of particular interest to this study is the evaluation of the effectiveness of the publication type the NLM designates as the “corrected and republished article”.

> The NLM fact sheet on corrections and republications (NLM) states:
> “Corrected and Republished Articles
> Occasionally, a journal may correct or amplify a previously-published article by republishing the article in its entirety, often to rectify an editorial or printing error in the original article. NLM creates a new citation for the republished article and indexes it with the additional Publication Type of Corrected and Republished Article [PT]. Text information appears in the PubMed citations for the original and republished articles (see examples

below) and a link is created between them. In the MEDLINE display in PubMed, the correction information appears in the RPI (Corrected and republished in) field and RPF (Corrected and republished from) field. “

Anomalous literature is different from normal publication types (from the perspective of citation analysis) in that each anomalous article has a counterpart in the index to which it is linked. For example, an article that has been corrected and republished by its producers, (authors or publishers), is referenced by the newer version, linking the two articles. According to Medline indexing protocols, the original version of the document will have its bibliographic entry changed to indicate that it is now not considered reliable, is linked to the newer, more correct and authoritative version and the connection between the paper’s citations is thus made mutual. Similarly, a retracted publication is linked to a retraction of publication and a duplicate publication is linked to its other versions. The biblioremeditative practice of correction and republication has resulted in the accumulation of a body of anomalous literature that is distinct from most bodies of corrective literature because it is comprised of nearly identical article pairs. In this study, the uncorrected, flawed version of a published scholarly article is referred to as the “original”, which is withdrawn by its authors or publisher in lieu of the “republication” or “republished version”.

Summary:

Information retrieval tools help researchers navigate the vast collection of scientific literature and identify relevant documents. Among these tools are

indexes, lists that direct researchers to documents of interest. Citation indexes are indexed without the judgment of indexers, instead exploiting the links made between documents by citation as the organizing principle. Indexes structured this way can be used to help researchers scan forward in time in the literature by identifying articles that have cited previous documents and can be used to perform citation analysis, a very useful technique for quantitatively examining the scientific literature. Categorical indexes, which arrange documents hierarchically based on indexer-selected descriptors, are another useful tool for managing and retrieving literature. These indexes, which match their hierarchical list with one or more other organized lists, are used to identify literature related to broad concepts and to identify and retrieve specific documents rapidly.

An index is an information retrieval tool whose intended function is to help researchers identify information to fuel scientific inquiry. The largest repository of bibliographic information for the biomedical sciences is the National Library of Medicine's database, Medline. In addition to assisting users in retrieving scientific literature, it also helps to maintain the integrity of the biomedical literature by alerting users to the status of articles that have been marked as being in some way anomalous. The NLM identifies corrective and anomalous documents by designating them with special publication type index descriptors. Among these publication types are included errata, articles that have been retracted because of error or scientific misconduct, duplicate articles and articles that have been corrected and republished.

Previous bibliometric studies have used citation analysis to evaluate the effectiveness of some types of corrective literature, most commonly retractions. This study proposes to examine the effectiveness of another biblioremediative technique, correction and republication. The study identifies a cohort of corrected and republished article pairs in the Medline database and then uses the Science Citation Index as the source for citation information about the selected documents. The frequency with which article versions are cited is compared and incidence of cocitation is tallied. Finally, the frequency with which the databases provide information about the nature of these anomalous documents is tallied. Collectively, these measures describe the extent to which republished articles have replaced flawed originals as references for subsequent authors.

Part 3 – Evaluation of Correction and Republication

This study evaluates the effectiveness of correction and republication based on three indicators:

1) Do authors preferentially cite original or republished versions of articles post-republication?

2) How often is post-republication citation of originals accompanied by citation of the republication ?

3) Do bibliographic entries for anomalous articles alert users to existence of the republication?

The impetus for this study is a desire to know if corrections to the highly important biomedical literature perform as intended. It does so by measuring the degree to which authors cite invalidated versions of article after republication of corrected versions and measures how often authors that cite originals post-republication also cite the republished version. It also measures citation behavior by performing a comparison of relative incidences of citation and co-citation of original and republished versions of documents at multi-year intervals post republication. It evaluates how often prominent sources of biomedical bibliographic literature provide users with information about the republished version. The results of this study describe the degree to which corrected versions of articles replace originals as a source of information for later

researchers (as measured by citation) and a possible reason for this phenomenon.

Central Question:

Is the practice of correction and republication effective?

1.1) Is there a difference between average citation levels of original and republished versions over time?

1.2) What percentage of documents that contain a citation to the original version of a corrected and republished article also contain a citation to the republished version of the article?

2) How often do bibliographic resources present information regarding the existence of republished versions of articles?

Question #1.1: *Is there a difference between average citation levels of original and republished versions over time?*

Ho: There is no statistically significant difference in the incidence of citation of original and republished versions of articles over time.

A comparison of relative incidence of citation of corrected and republished versions of article pairs is performed by examining the average level of citations over the lifetime of the document and at 4, 8 and 12 year intervals. This test determines if there is a statistically significant difference in citation levels of measures of corrected and republished article pairs over time. If republished versions are cited more frequently in subsequent years than original versions, the republications can be said to be replacing the originals. Similarly, if there is no difference in citation at 4 years but the republication is cited more than the original at eight or twelve years, it suggests that the republication is replacing the original as the definitive version. If the data do not recommend rejecting the hypothesis, this suggests that republished versions of articles are not replacing the originals as authoritative among authors.

Question #1.2: *What percentage of documents that contain a citation to the original version of a corrected and republished article also contain a citation to the republished version of the article?*

Ho: Articles that cite the original version post-republication cite the republished version at the same rate.

The hypothesis is answered by tabulating the number of articles that cite both the original version and the republished version of each of the articles designated with the “corrected and republished article” publication type index tag in Medline. This test measures the frequency with which users that cite the original document are aware of the other, as demonstrated by co-citation. A high degree of co-citation indicates that users are aware that the article has been corrected and republished. A high degree of post-republication citation of the original without citation of the republication would suggest that the republished version has not penetrated the consciousness of the research community.

Question #2: *With what frequency do prominent bibliographic information sources direct users to the authoritative version of corrected and republished literature?*

Ho: There is no difference between Medline and Web of Science in the presentation of information directing users to the complementary edition of the article pair.

This question determines how often common information sources make users aware of the existence, status and location of members of anomalous document pairs.

A study in the October 2003 JASIS by Porowoznek (Poworoznek 2003) examines the extent to which online physical science journals link original documents and errata. This study identified prominent online journals and scoured tables of content for errata. The author found 43 online journals that had examples of 3 or more published errata. The author then examined these journals for links between the erratum and the original document. Porowoznek observed considerable disparities in the policies of online publishers concerning the linkage of errata and the documents they correct. The author tallied the incidence of links from errata to original and vice versa. This study provides an example of methodology for approaching the question of evaluating to what

extent anomalous document pairs point to each other, alerting users to the existence of the counterpart article.

The Poworoznek study is relevant to the current research project because it evaluates the degree to which bibliographic entries for members of anomalous document pairs direct the user to their complementary member. This study is emulated by the current research in that it examines how often the entries for original and republished versions of corrected and republished articles alert users to the other member of the pair.

Assumptions

This bibliometric study relies on a number of assumptions regarding the literature and the phenomenon of citation:

It is assumed that an article that has been corrected and republished is perceived as having been completely withdrawn in lieu of the republished version. This assumption is justified because the act of republication is uncommon and so must be interpreted as the formal endorsement of the subsequent version. Further, NLM also identifies duplicate publications as aberrant literature and so cannot be assumed to be endorsing the two versions of a document, one clearly less reliable than the other.

It is assumed that if an author is aware of both versions he or she will choose to cite the republished version as the more definitive of the pair. This assumption is justified because publication is a formal exercise, the personal stakes of which are very high for the author. Authors are highly motivated to use the best possible resources to produce the optimal intellectual product.

It is assumed that the act of citation implies relevance to the citing publication and that there is a conceptual link between the two documents that relates them. This assumption is justified by the theoretical works of Garfield and Price, and by research findings, both of which are described in more detail in Chapter 2.

Limitations

The evaluated articles had to be indexed under Medline under the publication type “corrected and republished article”.

The documents were published in journal that is a part of the Core Clinical Journals subset. Formerly known as AIM-indexed journals, these sources rank among the most influential publications in the biomedical literature.

The articles were published between January 1, 1990 and January 31, 1999. This limitation allows for considerations of both publication lag and obsolescence.

The study was further limited by the selection of portals used. The study was limited to two high profile services, one public, free service, (PubMed) and one fee-based private service (Web of Science), both selected based upon their popularity and ubiquity. Though the Web of Science is a fee-based service, it was selected because of is high profile and because most scientists receive support from universities or other organizations and so are very likely to have access to this resource. Further both resources are designed in such a way that the same experiment can be performed on both systems, allowing for greater equality of results.

The study did not perform a citation context analysis (evaluating the characteristics of the citation) and is so justified for two reasons. First is the twofold limitation that citation context analysis relies on the subjective interpretation and evaluation of references in diverse biomedical sciences, requiring considerable knowledge and expertise in multiple scientific disciplines by the researchers, of which there must be more than one, to confirm interpretation. These requirements outstrip the abilities of the researcher both in terms of capacity and erudition. Investigation of the nature of post-republication citation may be of value, but it is out of the scope of this study. Secondly, research findings have confirmed the predictions of theoreticians that negative citation is uncommon and is not perpetuated in the literature in the same manner as positive citation and is subsequently of limited statistical significance. Thus, negative citation should not have a substantial impact on this evaluation of citation patterns and so a citation analysis to evaluate the nature of the citation (positive or negative, explicit or implicit), is unnecessary.

Summary:

This chapter has described the structure and functions of the academic literature at the scale of individual documents and at the level of the literature as a monolithic body and foundation of science. Scholarly publications have been accumulating for over 300 years and so the body of literature has inevitably acquired occasional flaws. Scientists have developed tools and procedures for

managing the literature and for making post-publication changes to flawed documents as a way of identifying and correcting errors while preserving the historical integrity of the scientific record. This study evaluates the effectiveness of one method of remedying errors, the practice of correction and republication. Previous studies have examined the effectiveness of such measures with regard to retracted publications using the method of citation analysis and this study to some extent emulates these earlier researches.

Overview of the dissertation:

Chapter 2 reviews the literature associated with this type of study. It discusses the topics introduced in this chapter, including scientific communication and the role of the published document in the sociology of science. The derivative nature of science and the impact and remediation of anomalous literature on the biomedical archive are addressed. The tasks of managing the literature and the applications of indexes as tools for doing so are examined. The study of science, scientometrics and specifically the examination of scientist's professional spoor as a methodology for such research is discussed and used as a justification of the research questions. Chapter 2 concludes with a review of relevant previous studies of corrective literature, describing their models and drawing upon them to construct an approach for research and

analysis. Chapter three details the selection of sources and datasets and describes the methods used to obtain and store the data. Chapter four presents analysis and results of hypothesis testing. Chapter five discusses the results and their implications and future directions of research.

Chapter 2: Pertinent literature

Introduction:

This chapter is intended to contextualize and explain the research project by describing related preceding research and providing theoretical background and justifications for the questions and selected methods. This explanation is accomplished by examining the media and analysis of formal scientific communication and by exploring how artifacts of publication can be exploited for studying science. The literature review is made up of three sections: The first part of the chapter examines scientific communication and the various roles the scholarly article plays in the professional and social practice of science. The first part of the chapter also examines the accumulation of documents into a body of literature and tools for managing it. The second part of the chapter explores the theoretical foundations of the study of science and scientific communications and the role that the published literature plays in this endeavor. This section examines the nature, history, theory, applications, units of study and critiques of pertinent areas of scientometric research, articulating the theoretical basis for bibliometric research in general and this study in particular. Relevant previous studies evaluating biblioremediative phenomena are reviewed and their underlying models examined and applied to this study in the third section of this

chapter. The chapter closes by considering the research questions and the approach to answering them.

Science & Scientific communication

What is Science?

A study of the artifacts of science must begin with attention to the question "what is science?" Much has been written about this innocuous-seeming question. In his seminal essay on the sociology of science, Public Knowledge, Ziman (Ziman 1968) posited four responses to that question:

Science is the study of the material world & natural phenomena

Science is the experimental method

Science is the process of arriving at truth by logical inferences from empirical observations

Science is public knowledge

Condensed into a single statement, science in terms of this study might be defined as: The process of accumulating knowledge and understanding by systematically asking and answering questions about natural phenomena in a manner such that others can understand, agree upon and independently reproduce those questions and answers.

The communicative nature of science

At its most fundamental level, science is the communicative process by which researchers share and build upon their knowledge. Robert Merton's classic The Normative Structures of Science described science as being governed by four basic principles, Communism, Universalism, Organized skepticism and Disinterestedness. (Merton and Storer 1973) The term "communism", (later changed to "the communality of scientific knowledge" (Small 2004)) refers to the public sharing of research results and is the means by which other researchers can engage in the "universal", "disinterested", "organized skepticism" that leads to the independent testing and validation (or rejection) of research results. Merton is given credit for describing the sociology of science, creating the first view of the study of science. Merton described the role of citation in science and his writings are the foundation of the discipline known as informetrics and the basis of the historical and sociological analysis of science.

The results generated by any scientist in any discipline must be subjected to review by other researchers before those results and the conclusions drawn from them can be made a part of the accepted scientific knowledge base and attributed to the author. (Merton and Storer 1973) As Price noted in "The Development & Structure of the Biomedical literature," (Warren 1981)

"We do not know if we have discovered something without such publication, because only through this process does the rest of the world community of our peers have a chance to validate the discovery by acceptance or rejection. Moreover, if it is accepted, they evaluate the discovery by using and incorporating it into all subsequent work." [2]

Not only does the researcher rely upon his contemporaries as part of the research process, he is enormously dependent upon the communications of preceding authors for theory, technique and inspiration. The acknowledgment of this debt is usually made in the bibliography of the published research. However, it is important to note that the formal mechanism of publication of results is not the only communicative action available to scientists. Informal channels, such as presentation of ongoing research at conferences and within departments provides an "off-the-record" forum for the discussion and evaluation of developing research prior to its being released to the global scientific community. In fact, this informal communication plays so large a role in the development of research that at least one observer has suggested that "most of the scientific information exchange relevant to the cutting edge takes place at the informal level". However, "when the reward or punishment is great...it is usually associated with the formal domain", and so is presented as a publication. (Garvey 1979) Thus, scientists are members of a community of professionals

who rely on channels of communication not only for the formal presentation of work but also as part of the research process.

Finally, science is cumulative. Research is built upon previous research findings and the understanding gained from them over time. As Zunde noted: “Progress in science is essentially determined by the stimulating effects of information accumulation and transfer.” (Zunde 1971) The research process relies on a public consensus regarding the nature and conditions of a discipline and is thus inherently social. New understanding can only be integrated into the body of knowledge by formally presenting it for public consumption; if it is not made public, it cannot be used as a foundation for further research. In the public sphere, unshared knowledge does not exist. Science relies on the tradition of the public sharing of findings over years, decades or even centuries; it is a social collaboration in which participants rely on each other to produce and extend understanding using shared information and insight.

Formal communication between scientists takes the form of the published scholarly treatise. Research is the mechanism by which scientists pose and test hypotheses through observation, experimentation and analysis. The process of posing questions and constructing experiments to answer those questions is cognitive. The writing of results and their organization into a document for the consumption of other researchers converts the researcher's ideas into concrete objects in the material world. As Becher (Becher 1989) observed, “The

published literature of any field is its most accessible and durable manifestation of the research activity it embraces." To use the terminology of 20th century philosopher Karl Popper, publication is the mechanism by which scientists move ideas (which occupy the world of mental objects (world 2)) that have been systematically evaluated using the foundation, techniques and theories of their discipline (the occupants of world 3, the world of products of the mind) into the world of physical objects (world 1) in an attempt to re-contribute to the world of products of the mind, (world 3).(Popper 1972).

The Document

Structure

Perhaps because publication serves so many different purposes, formal communication tends to be highly structured. Broadly speaking, following the title and declaration of authorship, the formal document presents an abstract, which contains a brief description of the research topic and results. Following the introduction, a description of techniques for data collection and analysis and a discussion of results is typically presented. The published article is an acknowledgment of scientific accomplishment and as such one of its functions is to acknowledge the contributions of preceding research. The last feature of a formal scientific publication is typically the list of references identifying the sources of information used in the research. This list of references to documents is known as a bibliography and is the basis of the science of citationology. Citationology is defined by Garfield as "the theory and practice of

citation and its derivative disciplines citation analysis and bibliometrics". (Garfield 1983)

The Citation

Citation is the practice of formally referencing previously published articles in ones own writing. Citations are references in the main text of an academic publication that refer to bibliographic entries to other articles. Citation is a complex behavior and much has been written regarding the motivations to cite. In 1964, Garfield enumerated 15 reasons to cite, including positive credit, identifying methodologies, substantiating claims, identifying original publications in which an idea or concept was first introduced and disputation of results. (Garfield 1964) Brooks confirmed the complex nature of citation behavior in 1986, using analysis of interviews with authors to show that citation motivation falls into 3 basic categories: (1) persuasiveness, (including positive credit, currency and social consensus), (2) negative credit and (3) reader alert and operational information. (Brooks 1986) A more recent study of the reasons for citing literature (Case and Higgins 2000) concurs with Gilbert and Brooks that citation is largely persuasive, finding that three types of judgments about cited works were found to predict citation: 1) That the work was novel, well-known, or a concept-marker, 2) That citing might promote the authority of ones own work and 3) That the work deserved criticism. (Case and Higgins 2000) Merton notes the tendency of authors to cite high-profile articles as a means of bolstering their claims, leading to a phenomenon known as the Matthew effect. [12] Gilbert and

Ziman commented on the need for an author to not only defend their priority in claiming credit for their “intellectual and scientific responsibility on the paper” but to also contextualize and justify the work. (Ziman 1968) Kaplan similarly observes in The Norms of Citation Behavior, that the list of references lends “intellectual and scientific responsibility on the paper” by demonstrating the author's familiarity with the field. (Kaplan 1965)

A parallel function of the references section of a manuscript is as a form of shorthand for describing methods. This is particularly the case with established methods or technologies, a practice noted by Cronin. (Cronin 2000) In 2003, Campanario identified four reasons why authors cite the works of other authors, agreeing that positive citation and persuasion were important factors in the decision to cite. (Campanario 2003) The use of the citation as a tool to convince an audience of the quality of an argument is a major reason to cite previous research. The bibliography of a paper is a list of references that give explicit credit to related research and is intended to convince the audience of the truthfulness of the assertions made and that the intellectual basis of the current research is solid. Further, the act of citation functions as a way of describing the context of the research, connecting it to the tradition of inquiry that has preceded it. The act of citation links the citing work with the referent work, creating an association between the two. The act of citing is a public declaration of relatedness between the citing work and preceding research.

The Document

Functions

The document has utility to scientists in a number of ways. The document is an object and so can be treated as a physical thing with a negotiable worth. One of the uses of publication that is of particular interest to the individual researcher is the role of publication in claiming credit for the research and results being published: Merton described citations as “atoms of peer recognition”. This function is important to scientists because it is the currency of their profession and a measure of eminence. Small notes “the dual function of cocitations as vehicles of peer recognition and constructed symbols for original achievements in science”. (Small 2004)

The document is also media, a mechanism to convey ideas and communicate with peers. A publication is also the object of the formal process of validation of knowledge claims, which is the principal mechanism of acquiring knowledge. Published literature is also meant to provide a guide to the reproduction of research and is intended to persuade readers of the accuracy and significance of the claims made. (Cronin 2000)

Though the document can be treated as a guide to performing a research and as a history of previous research in a discipline, the reader will only rarely perform the experiments described therein, assuming the honesty of the researcher and comparing the claims made with their own knowledge

Another major function of publication is the acknowledgment of intellectual priority through the process of citation. This use of publication as a form of currency by members of the scientific community is a major theme of Merton's exposition regarding the sociology of science. Authors acknowledge the contribution of antecedent work by noting it in print. The degree to which an individual is published and the influence those publications have influenced subsequent research is a key measure of professional accomplishment and stature. One of the ways in which the eminence of an article or author is evaluated is by measuring their impact on subsequent literature. This phenomenon and the controversy associated with it are discussed later in the chapter.

Many motivations exist to cite, and the use of citation as a way of establishing the bona fides of a research idea or procedure is one of the most important. This public acknowledgment is an implicit statement of relatedness and serves not only to bestow credit, but also to acquire persuasive credibility. Among the assertions implicit in the act of citation are that a preceding work is in some way related to the current opus and that the cited work is accurate and verifiable and that this lends credibility to the arguments made by the author. This faith in the verifiability of published literature lies at the core of the research endeavor. By acknowledging previous contributions, the author persuades the reader that the current work is legitimate. The act of citation simultaneously proclaims the derivative nature of the work while using the same claims to

acquire the patina of originality. The derivative nature of science assumes and utterly relies on the accuracy of the scientific record. The assumption that each article can be individually validated allows researchers to be confident that the accumulated literature for any given topic is reliable. (Smith 1981) (Brooks 1986) If the assumption of the validity of the scientific record can be challenged, science is undermined at its most fundamental level.

Publication is the process of writing research results into manuscript form and submitting them to a publisher for distribution. Publication is the culmination of the research process, by which completed research formally and publically becomes the intellectual property of the authors. The document has been subjected to editorial review by the publisher and has been found to be up to the minimum standards of the journal. Acceptance for publication is the benchmark indicating that the document has survived the first stage of the vetting process. Though editorial review is believed to date back to the 1731 Royal Society of Edinburgh, it was not a common practice in the world of scientific communication until the post world-war 2 era. (Kronick 1990) (Burnham 1990)] Publication is the point at which the author and editor's involvement with the validation process ends and the public's involvement begins. As Ziman noted, “The progenitor of a scientific paper is like a parent, whose early influence is decisive in the character of the child, but who cannot determine the career of his offspring in the adult world.” (Ziman 1968)

During the subsequent phase of validation, document is presented to the research community, allowing it to become the subject of debate, filtering out bad information and inferior ideas. Ideally, the community receives the document with what Price referred to as “organized skepticism” and the process of evaluating the claims made by the document begins. The evaluation of those claims by other members of the research community is a primary mechanism in the validation of research. As Ziman said,

> “..facts and theories must survive a period of critical study and testing by other competent and disinterested individuals and must have been found so persuasive that they are almost universally accepted. The objective of Science is not just to acquire information nor to utter all non-contradictory notions; its goal is a *consensus* of rational opinion over the widest possible field.” [11]

If an article is of sufficient utility, that article is likely to be cited in subsequent documents and particularly in those most influential documents, review articles. Review articles are critical assessments of the important and influential literature related to a given discipline. As such, they distill current understanding in a discipline; a review article “neglects the trivial, omits the mediocre, selects the significant and stresses the important”. (Virgo 1971) The citation of an article in a review indicates that the article is in some way worthwhile and represents an important feature of the intellectual landscape or

history of a discipline. Reviews elevate articles from the mass of publications and single them out as being noteworthy. In doing so, the review ignores papers that are judged to be less valuable to practitioners and they become more obscure. Thus, validation in the scientific community leads to a document having a higher profile than one that is judged to be of less merit, the latter being more likely to fade into oblivion. The published literature serves as a foundation for subsequent research. Findings of high utility and accuracy are long used as the basis for further research.

Thus, publication serves at least three critical functions in Science. First, it functions as currency and can serve as a measure of professional achievement. Secondly, publications are media, the channel by which scientists formally communicate. Thirdly, publication is the mechanism by which the public scrutiny of knowledge claims that underlie the scientific method is engaged. As Small noted, “The altruistic and communal spirit (of science) is driven by the self-interest of the scientist in gaining priority and symbolic recognition for their work. Discover, priority and recognition are thus inextricably intertwined with publication and citation links expose the socially validated structure of originality.” [13]

The Document

Anomalies in the literature

Occasionally, a publication is found to contain factual errors. When errors are recognized, the author alerts the publisher and a correction is published. It is

then incumbent upon the reader to search all subsequent issues to learn of any post-publication modification to an article. This post-hoc mechanism of alerting authors to changes in the literature is inefficient. Information retrieval tools such as bibliographic information providers are well positioned to inform users of changes to the literature. The intent of bibliographic database producers is to aid researchers by providing them with the best possible information to assist their endeavors.

The incidence of flaws in the literature is low. Discounting the publication types listed on the errata fact sheet that do not involve the repudiation of the original article, (Comment and response to comment, updates and patient summaries), the incidence of error in the literature is very low: a Medline search for the publication types “corrected and republished article”, “published erratum”, “retracted publication” and “duplicate publication” yielded a total of 3265 citations. This suggests an error rate of %0.022 among the approximately 15 million citations indexed in Medline.

Despite the fact that such anomalies are uncommon, they are important. Approximately 10% of biomedical articles indexed as being changed post-publication are also indexed with the publication tag “review article”. Review articles are highly influential documents and the impact of error in this subset alone could be significant. Further Kotzin observed that the potential impact of such flaws can be great if inaccurate information forms the basis for subsequent

research or patient treatment. Kotzin cites a published erratum in the Journal of Pediatrics in which a dosage is misprinted as milligrams (mg) rather than grams (gm) and an example in which a chemotherapy dosage was mis-transcribed from “every day for 28 days” to “every 28 days”. (Kotzin and Schuyler 1989) In another example of a highly cited article, the publisher printed the wrong figures in a paper about techniques to return blood to the heart immediately following heart attacks.

Database publishers have the ability to link corrected or retracted documents and the notices of changes to them and to alert the public to those changes. The National Library of Medicine is such a publisher and has approached the problem by identifying a number of types of changes in the literature and indexing the appropriate documents. The policies of the NLM regarding these documents are described by Colaianni (Colaianni 1992) and Kotzin (Kotzin and Schuyler 1989).

> “One of the ways NLM assists users is to add subsequent notices of errata, retractions, republications, duplicate publications and comments (including updates) to citations of articles indexed and available in NLM's online MEDLINE database. Users who search MEDLINE is informed if they retrieve a citation for an article that has subsequently been retracted, an article that has been found to duplicate another article, an article in which a substantive error has been noted, an article that has been

corrected and republished, an article that has generated a separately published commenting article, an original article that has been updated by a subsequent article, or if a summary for patients has been published. NLM updates and links the existing citations to subsequently published errata, retraction notices, comments and similar announcements." (NLM)

Since 1987, when a labeled, citable correction to a document is published, the NLM has annotated the bibliographic record of the original article with a reference to the notice of erratum. The NLM does not differentiate between publishing and scientific error, labeling corrections to both types of mistake as errata or corrigenda. According to the NLM, "Articles may be retracted or withdrawn by their authors, academic or institutional sponsor, editor or publisher, because of pervasive error or unsubstantiated or irreproducible data. NLM does not differentiate between articles that are retracted because of honest error and those that are retracted because of scientific misconduct or plagiarism. If the notification in the journal is labeled as a retraction or withdrawal, NLM indexes it as a retraction. The retraction must be labeled and published in citable form and NLM's policy states that the document must be clearly labeled as a withdrawal or retraction and must be signed by the publisher, the authors or their representatives. The NLM does not differentiate between retractions due to honest error and those due to malfeasance. Lindberg, the then-head of the NLM described the policies of his organization in a 1987 letter to Science, explaining that "…this approach offers Medline users more protection against

misinformation, -deliberate or accidental- than would be possible by simply browsing though the literature. A more aggressive approach by the Library would risk placing us in the inappropriate role of censor." (Lindberg 1987)

Since 1989, the NLM's policy has been that it applies a special publication type to the citation of a document if a comment regarding that document is published; the comment must be substantive and directed to that article, mere mention is not sufficient to warrant annotation. Subsequent responses to the comment are indexed using the "author reply" publication type. Articles that update previous articles are linked and indicated with the text "Update of" and "Update in" (see examples below). The article must explicitly state that it is an updated version of a specific previously published article or must appear in a journal that routinely publishes such updates as its primary content. NLM began to distinguish the updates with articles published in 2001 forward. A few journals indexed for MEDLINE routinely publish "patient" summaries of full articles that appear in the same journal issue. The summaries are intended for patients or the lay public to explain in non-technical terms the scientific or medical findings reported in the full article. Separate citations are created in MEDLINE for these "patient" summaries and the citations are indexed with the Publication Type of Patient Education Handout [PT]. The citations are also linked to the corresponding citation for the full, scientific article and appear with the text "Summary for patients in" and "Original report in".

Kotzin concludes: “Whether errors of omission, typographic mistakes, statistical carelessness, or deliberate falsification of data the results are the same – the distribution, transmission and repetition of inaccurate information. The NLM's policies do not address the root of the problem, the policies do have considerable value in controlling the proliferation of errors.” (Lincoff and Topol 1993)

Maintaining the accuracy of the literary record is the shared responsibility of authors, publishers and caretakers of scientific literature. Though Medline and other database producers are particularly auspiciously positioned regarding informing the public about anomalous literature, other players can make significant contributions. A 2004 JAMA article, describes the retraction policies of high impact journals, finding that 62% did not report a retraction policy. (Atlas 2004) Walter, found a similar paucity of policy among international libraries. (Walter 2000) Similarly, in 2003, Poworoznek found considerable variability in the errata-linking policies among high-impact physical science journals. (Poworoznek 2003) Though 40 years have passed since early calls for uniformity among producers regarding anomalous literature, little consensus exists today. (Marcus 2005)

The Document

The Literature

As a discipline matures, the volume of information published on a topic increases exponentially, making the task of critically evaluating every document in a subject area very challenging. The aggregate of documents for science in general or a particular discipline is often referred to as “The Literature”. Price describes the growth of knowledge as analogous to that of compound interest, growing exponentially by building on itself, but without the hindrance of withdrawals. The accumulation of publications makes managing knowledge in any field very challenging. Indeed, the intended role of the 17th century Philosophical Transactions of the Royal Society and Journal des Scavans was to help scientists of the time manage publications that were appearing at such a rate that it was impossible for one man to cope with his daily reading and correspondence. (Price 1986) Science is a social process in which many specialists who collectively represent a broad body of knowledge collaborate to extend their understanding. No individual can manage all of the information available to them. To limit the burden, researchers specialize and they use tools to help them manage knowledge and its repository, the accumulated scientific literature.

Indexes:

As the amount of material related to a discipline grows, managing that literature becomes more challenging. Methods for managing the literature have been developed as tools to assist in this task. Indexes are such a tool for

managing published information. An index is an ordered guide to the intellectual content and physical location of knowledge records. Indexes are lists of pointers or guides that typically do not provide information themselves, but employ a set of tags or descriptors that direct the searcher to the information source they seek. Cleveland describes four types of index, word and name indexes (also known as subject indexes), book and periodical indexes and information retrieval system indexes. Of the kinds of index, the information retrieval index is particularly germane to this study. Effective information retrieval tools assist with the selective, systematic recall of information and are judged by how well they reflect the content of the document and deliver it to the user.

Cleveland et al describe several kinds of indexes, based on the aspect of the literature being searched or “entry point”. (Cleveland 1983)

Author indexes

Alphabetic subject indexes – may be used to sort any bibliographic aspect, including subject terms, author names, sub-headings

Classified indexes – A hierarchy of related topics, starting with the general and working down to the specific, usually paired with an alphabetical list.

Coordinate indexes – Created by combining single index terms into new classes.

Permuted title indexes – Created by systematically rotating content bearing words in the title as subject entry points.

Faceted indexes – Used to derive classes of sub-topics for complex subjects

Chain indexes – A hierarchical list of concept markers, alphabetically arranged
Citation indexes – A list of articles with a sub list for each entry, identifying all articles that have cited that entry.

Of particular interest to this study are the classified index, of which type Medline is an example and the citation index, the most famous of which is the Science Citation Index (SCI), which is published by the Institute for Scientific Information (ISI). These indexes and the organizations that support them are very important features of the landscape of the scientific literature and are both integral parts of this study; a brief review of each in terms of their history, features and applications is warranted.

Medline

Increased spending on research by the federal government after WWII led to a dramatic increase in the scientific output of the United States. The US government sponsored a number of efforts to improve the management of scientific information. (Warren 1981) In 1954 the NLM began efforts to categorize the subject of biomedicine in the Subject Heading Authority List. The categorized lists of 5700 descriptors were published as the Medical Subject Headings (MeSH) in 1963. (NLM) In the early 1960s, the NLM also developed a computerized biomedical literature storage and retrieval system known as MEDLARS. The list of medical subjects known as MeSH was used as the core of the index at the root of the MEDLARS system. The MeSH thesaurus has since

grown from its initial 5700 descriptors to over 23,000 descriptors and is the foundation of the indexing system used by the NLM to manage the over 15 million articles produced by more than 4800 journals in the Medline database. (NLM)

Medline is a classified index, consisting of paired hierarchical and alphabetical lists of descriptor terms and special index entries (often called “tags”) that report aspects of the document (such as publication type) rather than describing its contents.. Its primary access point is the interface known as Entrez. Medline is the largest part of the PubMed database and is one part of the National Center for Biotechnology Information, (NCBI), the repository for biomedical information hosted by the National Library of Medicine. The information contained in PubMed's databases can be accessed using the Entrez interface.

The NLM offers numerous tools to assist users in accessing high-quality, up-to-date literature. One way the NLM assists users with this task is by adding subsequent notices of changes to status of articles to citations of articles indexed in Medline. As the Medline Fact Sheet on Errata states:

> “The National Library of Medicine® (NLM) has a long-standing tradition of providing access to information in the biomedical literature through quality programs and services. One of the ways NLM assists users is to add subsequent notices of errata, retractions, republications, duplicate

publications and comments (including updates) to citations of articles indexed and available in NLM's online MEDLINE database. Users who search MEDLINE is informed if they retrieve a citation for an article that has subsequently been retracted, an article that has been found to duplicate another article, an article in which a substantive error has been noted, an article that has been corrected and republished, an article that has generated a separately published commenting article, an original article that has been updated by a subsequent article, or if a summary for patients has been published. NLM updates and links the existing citations to subsequently published errata, retraction notices, comments and similar announcements." (NLM)

The Science Citation Index

Originally published 1963 in printed form as lists of linkages between document addresses, the modern Science Citation Index (SCI) is currently the largest collection of bibliographic citation information for published academic literature. Published by the Institute for Scientific Information, the Science Citation Index shows users not only what articles have been published, but shows the relationships between articles in print as well. Though some researchers did perform citation studies prior to the development of citation indexes, they tended to be limited in scope and tedious to perform. [2] The development of searchable indexes containing bibliographic information for hundreds of thousands of documents put an altogether more powerful tool into

the hands of researchers. Since its introduction, The SCI has been put to novel uses, including to study history of science and sociology of science in addition to its original purpose, as a tool to assist in information retrieval. (Garfield 1998)

Citation indexing is a method of indexing articles based on identifying articles that either cite or are cited by other articles. To quote Garfield, (Garfield 1970) “A citation index is an ordered list of cited articles, each accompanied by a list of citing articles. The citing article is identified as a source, the cited article as a reference.” As Baker describes in his review of the role of citation analysis in the sociology of science, (Baker 1990)

> “In citation indexing, publications are classified based on their conceptual relationships. If one article cites another, it is assumed that their intellectual content is related and that the citation represents a link to past knowledge. Citation indexes organize references hierarchically, source publications being bested under their respective citations. In this way a researcher can look up a favored document and locate source publications that have used this document as a cited reference. It is assumed that the two documents share a focus that might be of interest to the researcher.”

The indexes have been so successful they have found application outside of information retrieval, being used for such diverse applications as history of science (Garfield 1970) to determine funding priorities and measure eminence of

researchers. (Baker 1990) Use of evaluative bibliometrics for administrative purposes is controversial and many authors remind users to apply the techniques of evaluative bibliometrics with caution. (McGrath 1996) For a history of citation indexing and citation theory, readers are directed to Garfield's, 1983 book, Citation analysis, its theory and application. For a review of the controversy and debate about uses of citation analysis, readers are directed to the Wilson ARIST review. (Wilson 1999)

Though the SCI was the first broad citation index for the sciences, the concept of the citation index is not new. Garfield credits the Sheppard's Legal Index, (1874) as providing him with the inspiration for the SCI, and Weinberg (Weinberg 1997) points out that Hebrew scholars have used citation indexes since at least the 12th century.

The Document

Summary

Publication is the means by which scientists formally communicate with each other. The nature of this communication takes the form of structured, written documents describing the background and methods for a piece of research. The document typically consists of regular sections: introduction, methods, results and conclusion, followed by a list of bibliographic information of source material. This list of references is known as the bibliography and is of

considerable interest when studying scientific communication. The bibliography links a document to previous research efforts, functioning to describe the research and persuade the reader of its validity. The citation is also used to reference techniques and concepts and serves as a form of shorthand for researchers. Collectively, these elements are intended to present a clear description of a research project to an audience. (Case and Higgins 2000)

Publication of results serves several functions in the scientific community. At the personal level, publication is a means of acquiring professional prestige. At the document level publication is a formal means of communication, serving to describe original work and persuade an audience of its legitimacy. Paraphrasing Robert Merton, science is based on a public understanding of principles and procedures that can be applied anywhere and without preconceptions or prejudices regarding the outcome. Publication is the means by which consensus regarding concepts and methodologies is discussed, scrutinized and agreed upon by practitioners. The function of subjecting research results to public scrutiny is the broadest and most durable application of published literature. Public scrutiny and validation of results is the fundamental process by which scientific understanding grows. This public validation of results has at least three distinct stages which culminate in the integration of research results into the body of knowledge for that discipline.

The first kind of validation occurs at the editorial level, before publication. The second kind of scrutiny occurs when the article is published and read and critiqued by other members of that discipline. Ultimately, if the claims made are novel, (but conform to prevailing scientific norms), useful and correct, the document may be included in a review article, a special kind of document that is a distillation of the accumulated understanding for a particular discipline. Inclusion in a review is an indication of authority and quality. Articles that are not up to this standard tend not to be cited in subsequent literature and as time passes, become obsolete and vanish into obscurity. The rate at which a document becomes obsolete is known as the document's half-life and is calculated by measuring average citation rates over time. Journal half-lives can be found in Journal Citation Reports, an annual publication from the Institute for Scientific Information. An analysis of AIM indexed journals indicates a journal half-life of approximately 8 years. Egghe & Rousseau (Egghe and Rousseau 1990) provide a thorough review of obsolescence studies.

Ideally, after a period of public verification, a document's contents are accepted as part of the scientific canon. This accumulation of published literature constitutes a body of knowledge that a user can be confident is accurate. In reality, so many articles are published in a given year that it is impossible to personally verify the knowledge claims in every document a user encounters, so the user assumes that the contents are accurate by virtue of their having been filtered by editorial and peer review and presented in a reputable

forum for discussion and validation. (Garvey 1979) For the scientific community, these reputable arenas include journals, books, proceedings and reviews and other physical and literary venues.

There are situations in which erroneous information is present in the literature and must be corrected by direct means. Ideally, identification and correction happens not through scientific debate, but by recognition on the part of the publisher or author of the document that incorrect information has been published as though it were factual. In these cases, the parties who claim ownership of the document publish a notice identifying the flaw and the correct information. The practice of publication of notices of changes to documents and the modification of their bibliographic information is another mechanism for maintaining the integrity of the scientific literature.

Bibliographic information for a notice of correction or retraction contains information directing the reader back to the original article and the bibliographic entry for the original document is annotated to alert the user to the existence of the republication. The use of electronic databases allows information providers to alert users to corrections, republications, retractions, published errata & comments relevant to a referenced article. Users of Medline are informed if they retrieve a citation that has subsequently been corrected, commented upon or retracted. The annotation of bibliographic information is provided as a way of making the user aware of the status of documents whose status has changed

since publication. The annotation supplements the publication of the notice of correction as a means of making users aware of the change to the status of the article. This study is an examination of the effectiveness of one of these corrective measures, the phenomenon of correction and republication. Some researchers have suggested that electronic bibliographic information retrieval systems would themselves act as quality filters for the scientific literature by making it easier for readers to locate changes and minimize citation of poor data. The then head of the NLM noted: “The ability to correct the on-line file quickly is a great advantage of electronic information retrieval.” (Lindberg 1987) To some extent, this study is a test of that assertion.

The study of science

Introduction

The literature and history of the disciplines of bibliometrics, informetrics and scientometrics and the relationships between those disciplines have recently been the subject of several excellent reviews, including Hood & Wilson, (Hood and Wilson 2001) Wilson (Wilson 1999) and Borgman (Borgman and Furner 2002). Briefly, Informetrics is a blanket term that encompasses sociological and statistical studies of science, known as Scientometrics and Bibliometrics respectively. Scientometrics is typically associated with policy and social studies of science. The study of science based on the study of the tangible output of scientists, (documents) is generally referred to as Bibliometrics. The science based on the study of citations is known as Citationology and encompasses the fields of Bibliometrics and Citation Analysis. (Tague-Sutcliffe 1992) The definitions, history, assumptions & theoretical foundations, applications, units of study and limits of these areas of inquiry are described in the following section. Succinct definitions are offered by Diodato in the Dictionary of Bibliometrics. (Diodato 1994) Borgman offers a model for analyzing studies of scholarly communication based on three classes of variables: 1) Producers of communication, (authors, institutions, agencies, countries) 2) Artifacts, (articles, books, etc) 3) Concepts (including subjects, ideas and motivations for citing).(Borgman and Furner 2002) These variables constitute the basis of most bibliometric studies, including this one, which evaluates post-correction citation

levels as a measure of the effectiveness of the practice of correction and republication.

Informetrics

Hood's review of the literature of bibliometrics, scientometrics and informetrics begins by examining the history of the three disciplines, exploring where they overlap and where they are distinct. Hood points that there are numerous definitions found in the literature, (Hood and Wilson 2001) noting that Informetrics is succinctly articulated by Egghe and Rousseau as “Quantitative methods in library, documentation and information science” in their eponymous text. Since 1990, Informetrics has been widely accepted as a general term for scientometrics and bibliometrics (including citation analysis), with scientometrics dedicated primarily to policy studies and bibliometrics conceded more to library studies. According to Tague-Sutcliffe, Informetrics is the study of the quantifiable aspects of all information in all social areas, not just scientific communication and its artifacts and producers. It can incorporate, examine and utilize areas outside of the fields of scientometrics and bibliometrics.

Wilson describes the ways in which informetric research can be categorized; by type of information studied (citations, authors, indexing terms), method of analysis, or by research goals. Wilson identifies the basic unit of informetric analysis as a collection of publications, but notes:

> "More correctly, in informetrics it is usually only surrogates that are studied, the bibliography of records. It is helpful to see each publication (record) as a repository of properties, (bibliographic fields) with variable-values, such as language, publication year, containing journal, authors and title."

Wilson goes on to note that a more complex view of informetrics allows for the identification of quasi-links between documents or other literary artifacts. Regardless, the analysis is concerned with the links or relationships between elements in the literature. (Wilson 1999)

Bibliometrics and scientometrics focus their analysis on a number of areas, including statistical studies of word and phrase frequencies, citation analysis and obsolescence studies. Tague-Sutcliffe also notes two phenomena that have not traditionally been viewed as part of bibliometrics or scientometrics but that are covered by informetrics: The definition & measurement of information and the identification of types & characteristics of retrieval performance measures. Borgman identifies three variables used in informetric studies: producers, artifacts and communication concepts.(Borgman 1990) The theoretical and practical aspects of retrieval performance evaluation are presented in the annual conference series, International Conference on Research and Development in Information Retrieval.

Scientometrics

Scientometrics is often defined as the “quantitative study of science and technology”, or more thoroughly as “the study of the quantitative aspects of science as a discipline or economic activity. It is part of the sociology of science and has application to science policy making. It involves quantitative studies of scientific activities, including, among others, publication and so overlaps bibliometrics to some extent.” (Tague-Sutcliffe 1992) The field of scientometrics has so grown in importance since it was first proposed that a refereed journal of the same name was founded in 1978. The subtitle of that journal suggests a practical definition for the term by declaring that it is concerned with “All Quantitative Aspects of the Science of Science, Communication in Science and Science Policy”. Besides the study of literary output, scientometrics explores questions of sociology of science, the social, political and economic roles of scientists and the anthropology of science. Garfield offered a slightly different definition in 1988: “Scientometrics is the application of quantitative methods to the study of the history and sociology of science.” In this case, the narrower Tague-Sutcliffe definition (“The study of the quantitative aspects of science as a discipline or economic activity.”) of the term is preferred.

The proposition that science itself is a potential field of scientific inquiry is often credited to the author of the 1986 citation classic Little Science, Big Science, Derek DeSolla Price. (Price 1986) In this series of essays, the physicist turned historian-of-science suggested that as a discipline matures, the degree of

publication in that field rises exponentially and that this abundance makes the residue of scientific communication an attractive subject for study. The accumulated literature of a discipline is a useful object of study for at least two important reasons: The number of documents is large enough to be appropriate for statistically accurate sampling and secondly, published documents are treated as a proxy for scientific behavior and can be collected unobtrusively.

Wilson distinguished between the fields of Scientometrics and Bibliometrics while noting their areas of overlap, particularly their common focus on the literary output of scientists as the basic unit of analysis. Like bibliographic studies, scientometrics examines the literature of science and scholarship, but also extends into non-bibliometric fields of inquiry such as studies of the sociology of science. An excellent review of scientometrics as a policy studies discipline is provided by Van Raan.(VanRaan 1997)

Bibliometrics

Because it is both the physical product of their exertions and the media of their formal communication, much of the study of science is concerned with the analysis of the literary output of researchers. The area of informetrics that studies scholarly communication through the analysis of published works is known as Bibliometrics. Though the first bibliometric study is generally accepted

to have been performed in 1917 by Cole & Eales, (Hood and Wilson 2001) the term did not acquire its current definition “The application of mathematics and statistical methods to books and other media of communication” until it was proposed by Pritchard in 1969 as an alternative to the more nebulous “statistical bibliography”. Broadus provides the succinct “A quantitative study of physical published units, or of bibliographic units, or of surrogates of either” as a definition for bibliometrics. Wilson noted that early studies were typified by two characteristics: 1) The recognition that bibliographies could be used as objects of study and could be treated as surrogates for the literature and 2) an orientation to seeking numeric data and analyzing it by statistical or other mathematical methods. (Wilson 1999) White's 1989 review of bibliometrics observes that the goal of bibliometrics “...is to provide evolutionary models of science, technology and scholarship”, suggesting that “Bibliometrics is to publications as demography is to peoples”. (White and McCain 1989) Borgman identifies three variables used in informetric studies: producers, artifacts and communication concepts. (Borgman and Furner 2002) Bibliometric studies typically rely on counts of the frequency with which some event occurs, which are subsequently treated as the probability of occurrence. (Borgman 1990)

Bibliometrics offers a powerful set of tools for studying scholarly communication. The media of scholarly communication, published literature and more specifically the surrogates of the published literature, (such as abstracts or bibliographies), can be used as the basis for analysis. As Borgman notes:

"One general method by which communicative activity may be explained, interpreted or otherwise understood is to consider the objects, agents, events, products and contexts of such activity as entities to be counted, measures or quantified. Numerical data may be collected about samples drawn from general populations of such entities; these data may be analyzed using statistical techniques; and conclusions drawn about the nature of the populations and about the existence of certain causal processes." (Borgman p 3)

A basic unit of analysis in bibliometric studies is the "degree of citedness" or the frequency with which a particular document is referenced by other documents. Bibliometric studies are very often concerned with the links between documents, exploiting the nature of the relationship formed when one document references the other. Historically, this relationship was restricted to the phenomenon of citation, however, due to the growth of public online information resources, links between information objects have become ubiquitous. Because of this proliferation, the terms "citing", "citation" and "citation analysis" have begun to have more restricted meanings. When studying scholarly communications, the assumption is that the focus is on relationships between scholarly works published in academic journals that are principally distributed in hard-copy format containing a list of bibliographic references to other documents at the end of the citing document.

The analysis of the relationships between journals, authors or concepts can be used to study aspects of behavior other than linking (relational link analysis) or to study the act of citing itself (evaluative link analysis). The application of relational link analysis to the mapping of literature was explored the 1997 ARIST review by White & McCain. (White and McCain 1989) In relational studies, links are analyzed to determine the degree or direction of relatedness or closeness of artifacts. The scores of link counts can be used to map or graph the degree to which objects of study are related and they can be used to assist in information retrieval. Recent developments in the area of web-based information retrieval have demonstrated how applied citation analysis can have important and far-reaching applications. The evaluation of impact or eminence of an object (artifact, producer or concept) is another application of linkage analysis, though advocates of the use of citationology warn against misapplication of the method when making administrative decisions.

Citationology & Citation Analysis

As Wilson notes in her 1999 review of Informetrics, citation analysis may be conveniently subdivided into three major domains: 1) The theory of citing, 2) Citation performance and usage measures and 3) co-citation analysis and literature mapping. Garfield has suggested combining all three domains under the rubric of citationology.

Garfield offers the term “citationology” as the name of the domain of research that includes “the theory and practice of citation, including citation analysis and

bibliometrics". (Garfield 1998) In the same review of the theory of citation, Garfield notes several "commandments" or "maxims" of citation analysis. First, citation relevance cannot be predicted, as references are the result of a symbolic language unique to the author. (Cronin 2000) (Small 2004) Secondly, "If author X cites the work of author Y, regardless of the reason, then this fact alone makes the citing paper relevant to author Y and, furthermore author X may be interested in other papers that cite Y." The third maxim reminds the user of the necessity of comparison of equivalent units or categories.

The theory of citing is attributed to Robert Merton, who articulated a theoretical view about the sociology of science and the role of publication. His essay "The Normative Structure of Science" is the basis of the parallel fields of scientometrics and citationology. Regarding the theory of citing, in her ARIST review on Informetrics, Wilson goes on to note that the practice of citation analysis involves making some assumptions. If it can be assumed that all citations are equal with respect to informing and reporting research then several conclusions can be made:

1) The frequency with which a document is cited by a body of a measure of its use;

2) Diminishing citation is a sign of growing obsolescence,

3) The more two documents are co-cited, the more likely they are to be related.

Rejection of these assumptions throws the entire enterprise of citation analysis into question. The process of debate and rebuttal in the literature regarding the merits and shortcomings of citation theory has been vigorous and thoroughly documented. (Small 2004) Validation studies have gone far towards endorsing the reliability of citation analysis; such techniques must be appropriately applied and are not infallible but do provide genuine insight into the dynamics of scientific communication.

Applications of citation analysis

Citation analysis is the best known and most frequently used of the informetric methods. Citation analysis is the study of the linkages between documents caused by the practice of reference and citation, particularly by counting the number of published references to a scholarly work. Many reviews of citation analysis exist; readers are particularly directed to the Wilson review and Garfield's 1983 text. Of note to this study is the fact that researchers have applied this technique to evaluate the effectiveness of retraction of fraudulent articles.

Electronic citation indexes have encouraged the development of more advanced citation analysis techniques such as bibliographic coupling and co-citation analysis. Bibliographic coupling is a method used to link citing documents based on common citations whose function is to evaluate how closely a pair of objects is related. (Kessler 1963) If a reference is shared by two

documents, they share a unit of coupling. Coupling strength is determined by the number of citations a pair (or larger set) of documents share. The theory and applications of bibliographic coupling were explored by Weinberg in 1974. (Weinberg 1974) Co-citation analysis (White and McCain 1989) (Campanario 2003) is a bibliographic method whose function is to measure the relatedness of cited documents rather than source documents and is applied as a tool for "mapping" an object of study. Evaluation relies on counting the number of times a given pair of articles is cited in source documents. A pair has a high degree of relatedness if many articles cite both members of that pair. Co-citation analysis can be applied to authors as well, identifying producers who are doing similar work and identifying "invisible colleges" (Price, (Price 1986)) and to co-word analysis, as a means to identify related concepts in the literature (Leydesdorff 1998). In the case of this study, co-citation is applied as a measure of user awareness of the status of original articles as having been withdrawn in lieu of later versions, as previous researchers have done.

Another common form of citation analysis is known as citation context analysis. This technique involves identifying the characteristics of all incidences of citation of a document. Attributes examined include the nature of the citation, (positive or negative, implicit or explicit)and the location of the citation in the citing document, (Introduction, methods, discussion, etc.) This technique has been performed as part of citation analysis by numerous authors and the similarity among results is striking: negative citation is uncommon and citation is

more likely to be implicit than explicit. That is, citation tends to be general rather than specific, perhaps referencing a topic or theme rather than a specific datum. Details about the use of citation context analysis can be found in the Wilson ARIST review and examples of citation context analysis include Pfeifer, Garfield, and Wright (Pfeifer and Snodgrass 1990; Wright 1991; Budd, Sievert et al. 1998)

Egghe & Rousseau identify three applications for citation analysis, “qualitative and quantitative evaluation of scientists, publications and scientific institutions; modeling of the historical development of science and technology; and information search and retrieval”. Garfield asserts that citation analysis can be used to describe intellectual relationships and for mapping disciplines and research fronts, and to describe the history of science. (Garfield 1983),

Limits of Citation Analysis

Proponents of citationological methods are careful to point out that such indexes and databases must be correctly designed and that comparisons and inferences are appropriately made. (McGrath 1996), (Garfield 1983) MacRoberts and MacRoberts have offered numerous critical reviews of citation analysis, enumerating problems with the technique. (MacRoberts 1996) Rebuttal and debate of these points and those raised by other authors, has played out in the literature over years. (Borgman 1990; Wilson 1999) Though considerable ink has been expended on both sides of the debate, the consensus appears to be that if citation analysis is appropriately and correctly applied, (both contextually

and in terms of units of analysis), it is a technique with many useful applications. Results of studies and researcher's experience seem to favor the citationologists over their critics regarding the use of citation analysis as an evaluative technique.

The study of science - Summary:

The works of Price and Merton are generally credited with being the origin of bibliometrics. Merton's writings on the sociology of science described the role that publication has in the professional interplay of researchers, providing a theoretical foundation for scientometrics and citationology. In Big Science, Little Science, Price explained how by analyzing inter-document citation patterns details of the landscape of science could be described in a variety of ways. This theoretical work, coupled with the literature management technique known as citation indexing, (whereby articles are indexed on the basis of reference and citation rather than indexer interpretation), provides researchers with the ability to evaluate scientific literature based on relationships between documents.

One of the applications to which citation analysis has been put is the evaluation of the effectiveness of procedures for repairing flaws in the scientific literature. To date no such studies have been performed on the documents identified in the Medline database as "corrected and republished articles". (Studies of the sort that evaluate other anomalous literature types are the subject of the next section.) This study applies the technique of citation analysis to measure the degree to which republished versions of articles have supplanted

original versions as authoritative among researchers, interpreting citation as an author's endorsement of a document as being valid and relevant. This study then examines the degree to which researchers are provided with information about the link between versions by bibliographic information sources. By measuring the frequency with which authors cite original & republished versions and by measuring the degree to which users of bibliographic systems are presented with information regarding the status of original & republished versions, insight into the effectiveness of correction & republication as a technique for correcting flaws in the literature is acquired.

Preceding research

The purpose of this study is to evaluate the effectiveness of the phenomenon of correction and republication in the biomedical literature. The project's goals are met by evaluating the degree to which correction and republication effects information retrieval and citation behavior. If there is no difference between citation levels for corrected and republished versions of articles, then correction and republication is not effective at preventing the citation of flawed publications that have been officially withdrawn by their authors or publishers. The degree to which common literature information retrieval systems make users aware of the status of these articles and the existence of newer, definitive versions is assessed as a potential explanation for continued citation of corrected articles.

The NLM identifies a number of publication types that are unusual in that such documents are linked to another, closely related document. This link is typical of the relationship formed by inter-document citation, but is atypical in that the linkage is between the documents themselves rather than between content of the articles. These special referential links are designated differently than content links in indexes and the relationship is identified by a special bibliographic index entry rather than the more common descriptor, a term that represents some significant aspect of the article's contents. NLM identifies these documents using special publication types, an index field included for articles in the Medline database.

As part of their mission to provide researchers with high-quality information, the NLM began to designate special document types in the late 1980's. Among the many recognized publication types, there are a number of kinds of corrective literature. These remediative document types include errata, correction & republication, duplicate publication and retraction. The first of these types to receive formal designation was the retraction in 1984. In a letter to the editor in Science, Lindberg described NLM's policy for identifying retracted articles in Medline, noting the identification of 36 retractions since the implementation of the policy 3 years earlier and heralding a similar designation "published errata" in 1987. Inclusion of "comments to articles" as a document type followed in 1989 and the "corrected and republished article" document type was added in 1991. Lindberg states "The ability to correct the online file quickly is a great advantage of electronic information retrieval." "We believe this approach offers Medline users more protection against misinformation – deliberate or accidental – than would be possible simply by browsing the literature." (Lindberg 1987)

In a special issue of JAMA published in March 1990, two articles examining the degree to which retracted articles were being cited were published. These are among the earliest studies evaluating the effectiveness of retraction and both articles utilize the method of citation analysis to evaluate the impact that retraction has on citation behavior. Pfeifer and Snodgrass

questioned whether “current methods to disseminate knowledge of retracted publications were adequate to prevent their future use.” To answer this question, the authors identified retracted articles using the published Index Medicus. The researchers collected their sample of retracted articles by reviewing the Index Medicus and by manually reviewing editorials and reports of fraud in the scientific literature. The authors applied citation analysis to this cohort, identifying every instance in which the retracted document was cited. In order to account for articles that were in print at the time of retraction (and thus could potentially be legitimately citing flawed a retracted article), the dataset was limited to articles published one year after the date of retraction or later. To determine what impact retraction had on subsequent citation, a control group of non-all retracted works from the same journals was established and citation of these articles tracked over the same time period.

Using this data, the authors generated a cumulative citation curve, comparing the curve of incidence of citation over time of the retracted and non-retracted article groups. The authors conclude that citation of previously invalidated works is “abundant and ubiquitous”, observing a 35% diminution of citation among retracted articles compared to non-retracted articles from the same journals. This figure indicates “invalid work is not being effectively purged from the literature.” The authors note the responsibility and possible shortcomings of the editorial and peer review process in addition to pointing out the responsibilities that publishers and indexers play in alerting the public to

changes in the state of the veracity of the literature. (Pfeifer and Snodgrass 1990)

The Pfeifer et al study is relevant to the current research project because it is an early example of the use of citation analysis to examine of the effectiveness of a biblioremediative technique. This study is influential in that it suggests that user awareness and indexing patterns may explain continued citation behavior. The Pfeifer study is also emulated by the current research in that it relies on the Science Citation Index for citation data and that it examines incidence of citation after the original document has been officially designated as invalid. The current research project differs from the Pfeifer study in that it compares members of corrected & republished article pairs, (rather than comparing selected articles and controls from the same sources) and that it uses a different statistic to make the comparison, utilizing a t-test rather than applying a comparison of plotted curves.

In the same issue of JAMA, Garfield & Dorff published findings based on their examination of the research impact of fraud on the scientific literature. Like Pfeifer et al, the authors used the method of citation analysis. Garfield's study differed from the Pfeifer study in that the authors identified a group of retracted articles published by one author in a three year period. In 1998, researcher Stephen Breuning was found to have repeatedly committed scientific fraud and a significant number of his works were vitiated. Garfield & Dorff generated citation

counts for each of 20 cited articles. Additionally, a citation context analysis was conducted to determine how authors were citing the discredited author's work. Analysis of non-self citations, (approximately 60% of the citations to the author's works), shows a peak of citation within five years of retraction followed by an annual diminution of citation. The citation context analysis performed indicated that approximately 30% of citations to this cohort were explicitly negative.(Garfield and Welljamsdorof 1990) The authors conclude that the scientific literature is purging itself of literature that has been identified as being flawed. This interpretation is at odds from that of Pfeifer's group in that the former group interpreted a 70% tacit or explicit positive citation rate as evidence that inappropriate citation is rampant. It would be informative to revisit this study and incorporate citation data for the 15 year period since the study was published to see if citation patterns have continued as Garfield's group predicted.

In 1991, Wright performed an analysis of citations of retracted literature as part her doctoral research.(Wright 1991) Wright's study included a citation analysis of 53 retracted articles as a way of addressing a pair of research questions: 1) Does retraction depress subsequent citation frequency and 2) Are post-retraction citations positive or negative? Wright's first question was answered by comparing the number of citations that each article in the cohort received in the 2 year periods before and after retraction. A directional t-test was performed, detecting a statistically significant difference in pre- and post-retraction citation levels. Citation context analysis was applied to the cohort and

Wright found a 90% rate of implicit or explicit positive citation. Wright concluded that the continued affirmative citation indicated that some retractions are going unheeded and that invalid information may be perpetuated through subsequent citation.

Wright's study is relevant to the current research project because it measures the relative citation levels between document pairs. As was mentioned earlier, anomalous documents such as duplicate publications, retractions and corrections are atypical in that they come as pairs, (or possibly, sets). This study suggests a way to compare members of document pairs with each other and to do so in a manner that obviates concern about diminution of citation through obsolescence. This study is emulated by the current research in that it compares incidence of citation of members of document pairs, (Original and Republished versions of corrected articles). This project differs from the Wright study in that it examines a longer post-republication period and it includes a 1-year publication lag to account for articles that may have been in press at the time the republication was released and to allow time for indexing of the new version.

A 1994 study by Whitely sought to determine whether scientists can detect fraudulent results and to identify corrective measures that are most effective at purging fraudulent results. The author compared articles produced by a publicly-exposed perpetrator of scientific fraud, (Dr. R. Slutsky), to control articles from

the same issues in which the retracted articles occurred. Citation data was collected from the Science Citation Index for both groups and transformed into scores based on relative number of citations, which were tracked over an 11-year period. The author found that prior to the public questioning of the authors work, Slutsky's articles were cited at the same rate as other articles from the same journals. After Slutsky's work was questioned, citation of his articles diminished. Further, the author found that citations diminished further after the publication of a review of Slutsky's work by UCSD in 1987. Citations did not decrease after the appearance of retractions in print or in Medline. Whitely concludes that users do not and probably cannot, identify articles that are fraudulent if they have made it through the peer-review process and into print. However, when alerted to the status of such articles, the scientific community responds by reducing citation of those articles. Whitely further concludes that news articles and reviews of the author's work were more effective at alerting the scientific community than other print notices in scholarly publications or in Medline.

Whitley's study focuses on literature whose retraction was highly publicized. The practice of focusing on the work of an author whose disclosure of misconduct was particularly public has been followed by other researchers, including Garfield (Garfield and Welljamsdorof 1990) and Kochan (Kochan and Budd 1992). Though all of these studies focused on highly publicized bodies of work, (which theoretically ought to be shunned by authors and therefore should

show a lower incidence of citation than less well-known work), all noted significant post-retraction citation.

Whitely's study is relevant to the current research project because it compares the incidence of citation of formally withdrawn articles over time. Further, it notes that user awareness of the status of retracted articles appears to be critical to decreasing citation. The current study compares incidence of citation of groups over 4-year intervals and it evaluates how often users are provided with information about the status of anomalous documents as a possible explanation for post retraction citation.

A 1999 study by Budd et al examined 235 retracted publications that had been indexed in Medline, determining reasons for retraction and incidence of citation to the articles. The Budd group considered three questions: The identity of the retractor, the reason for retraction and use of retracted articles by subsequent researchers. The authors found that almost 81 % of retractions were made by authors, and that approximately 37% of articles were retracted due to perceived misconduct. Regarding citations, 278 of 299 citations (93%) to the document set made in AIM indexed journals were implicitly or explicitly positive. Of 2034 citations made to the set of 235 retracted publications identified by ISI, 275 (13%) were explicitly positive, as were nearly 90% (1091 of 1214) of non-AIM journal citations. The authors used a chi-square test to establish that the incidence of positive citation of post-retraction articles was lower among AIM

indexed journals, suggesting the possibility of higher standards for citation among this group. The authors conclude that the results of the study strongly indicate that retraction, even when noted in the Medline database, does not ensure reader awareness and a diminution in referencing of retracted works. This study is emulated by the current research in that it measures incidence of post-withdrawal citation and it limits the sample to the clinically important group of journals indexed in Medline as the Core Clinical Dataset and that it is includes a 1-year delay to account for indexing and publication lag.

These studies have evaluated the continued citation of retracted literature by using citation analysis and citation context analysis on post-retraction citations. All of the previous studies examined retracted articles. Articles are retracted because of fraud or error. The former reason makes this kind of post-publication modification particularly high-profile. Very few studies of other corrective mechanisms of the literature exist. Corrections and republications have not commanded the same level of attention as retractions though their impact may be no less significant. These studies have evaluated the continued citation of retracted literature by examining the degree of citation and the nature of citation through citation context analysis. The results of content analysis are quite similar. Post-retraction citation is usually positive and continues to s a significant extent after the article has been retracted. No similar studies evaluating the citation of other documents that have been officially changes post-publication, including errata and correction & republication.

A study examining errata exists, though it does not evaluate citation levels or types. Using a novel method, the Poworoznek study explores the link established between documents when a post-publication modification is released. The 2003 study describes online access to errata from the user's perspective by examining the degree of linkage between original articles and corrigenda in online versions of high-impact physical science journals. The dataset was obtained by examining tables of contents for a variety of journals of interest and searching SCI for articles citing members of the document set. The author observed considerable variability among publisher's linking errata to original papers, finding that among 26 of 43 journals reviewed (60%) included at least one link connecting errata with original papers. Porowoznek's study is relevant to the current research project because it evaluates the degree to which bibliographic entries for members of anomalous document pairs direct the user to their complementary member. This study is emulated by the current research in that it examines how often the entries for original and republished versions of corrected and republished articles alert users to the other member of the pair.

The practice of using citation counts to evaluate the effectiveness of methods for articles from the scientific literature has numerous precedents. The first corrective literature type identified by the NLM was the retraction. Examples of studies evaluating the effectiveness of retraction include Pfeifer 1990 and

Garfield, 1990. The Pfeifer study compares the citation of a selection of retracted articles to the incidence of citation for a control group to determine if the retracted articles are being rejected by authors. Garfield measured incidence of citation of a set of repudiated documents by one author over time and noted a pattern of diminishing citation. Budd et al measured post-retraction citation over time and performed a citation context analysis to establish that most citation is implicitly or explicitly positive.

This study differs slightly from these preceding studies in that while it measures incidence of citation of withdrawn articles, it compares the incidence of citation of thee articles to the complementary version of the document, the republication. The phenomenon of correction and republication is unusual in that the process generates a document pair, both of which may appear to be useful. The phenomenon of retraction also produces a document pair, however the statement of retraction is not typically easily confused for the original publication of findings.

Numerous authors have noted the roles that various members of the scientific community play in maintaining the integrity of the scientific literature. Incidence of post-retraction citation is well documented and a number of possible explanations for the phenomenon have been posited, (among them editorial sloth or incompetence and author ignorance). This study measures how often

bibliographic indexing and retrieval systems provide searchers with information regarding the corrected version of flawed biomedical literature.

Bibliographic databases are tools to assist researchers by providing high quality information, and such systems are evaluated by the quality of the material they present their users. If authors consistently cite literature that has been withdrawn, it seems reasonable to ask if users have access to correct information, or if they are being fed erroneous material. If information retrieval systems present the user with the most authoritative version of a document and users cite the older, withdrawn version anyway, then IR systems are not to blame for the error and scientometricians must look elsewhere for the reason for erroneous citation.

Summary:

Science is fundamentally a communicative activity. The validation of results, the acquisition of credit and reward and the payment of intellectual debts are all features of communicative action in science. Because communication plays so many roles in science, it tends to be structured and formal. One important aspect typical of scholarly articles is the tradition of referencing earlier, influential works, a practice known as citation. Citation is complex behavior; it serves to acquire and bestow credit, as a specialized language to convey procedural information and paradoxically to simultaneously assert originality

while seeking to persuade audiences of legitimacy by establishing the derivative nature of the work. Regardless of the motivations behind referencing, the effects are useful. The act of citing creates a link between the document and the work that it cites. The author is making an implicit statement that there is a relationship between the citing article and the referent. Citation analysis is the study of these relationships.

In addition to being a vehicle for attribution and receipt of credit as well as a mechanism for validating and advancing science, the scientific literature can also be used as the source of data for studying aspects of the literature itself. In Little Science, Big Science, Derek DeSolla Price articulates why the literature of science itself can be treated as the subject of study. Price describes publication in terms of Merton's theory of science as a sociological process and explains that these aspects make publications predictable and suitable subjects for study. A mature discipline produces so much literature that the documents become a body of records large enough to constitute a statistically treatable dataset. Formal communication between scientists lends itself to analysis because it tends to be predictable in a number of useful ways, particularly in that bibliographic entries can be used as proxies for their referents. Price describes how bibliographies produced by scientists could be treated as an unobtrusive data set for studying some communicative aspects of science.

Tools for the management of the amassed scientific literature have become indispensable. Information management tools such as indexes and the databases built on them assist users in pinpointing relevant literature among the vast number of published articles. Indexes are organized lists of descriptors that can be searched to identify articles whose bibliographic information matches those descriptors. If these descriptors are intended to identify articles that have had some aspect of their veracity challenged, then the index is functioning to alert users to the status of this group of articles.

This study follows the example of previous inquiries by exploiting the characteristics of the literature described by Price and the practice of citation described by Merton to study one subset of the total biomedical literature, namely corrected and republished articles. Corrected and republished articles are special documents that have been formally withdrawn by their producers and replaced with a new, more authoritative version of a document. This study examines citation of corrected and republished articles and the how often prominent literature information retrieval systems provide users with information about the link between corrected and republished document pairs.

The purpose of this study is to evaluate the effectiveness of the phenomenon of correction and republication in the biomedical literature. This is accomplished by evaluating the degree to which correction and republication effects information retrieval and citation behavior. If there is no difference

between citation levels for corrected and republished versions of articles, then correction and republication is not effective at preventing the citation of flawed publications that have been officially withdrawn by their authors or publishers. The degree to which common literature information retrieval systems make users aware of the status of these articles and the existence of newer, definitive versions is assessed as a potential explanation for continued citation of corrected articles.

Chapter 3: Methods

Data are presented in Appendix [A].

Objective:

The central purpose of this study is to evaluate the effectiveness of the practice of correction and republication of flawed literature. This study evaluates the effectiveness of correction and republication based on the following indicators:

1) What is the post-republication incidence of citation of original and republished versions of articles?
2) How often do authors co-cite corrected and republished articles?
3) How often do searches for corrected articles yield bibliographic information about the corrected versions?

The central research question is important because the effectiveness of correction and republication of clinically relevant literature is untested. Previous citation studies have questioned the effectiveness of retraction as a method of

reducing citation of invalidated literature. It is important to know if corrective measures are having the desired effect of identifying flawed literature so that it is not erroneously applied in subsequent research. The biomedical literature is the collected body of scientific knowledge in an area that is of direct relevance to modern clinical and research health care. The maintenance of the integrity of the literature is important because errors can have negative scientific, social, economic and human health consequences.

The research questions evaluate the effectiveness of the practice of correction and republication by measuring the degree to which publishing researchers are aware of modifications to the literature as reflected by their citation behavior. Author ignorance of post-publication changes to the literature is a frequently cited as a possible explanation for inappropriate citation; the degree to which information retrieval systems inform users of changes to the literature is examined as a possible explanation for continued post-republication citation of corrected articles.

Post-publication modifications are published and indexed as part of an effort to maintain the integrity of the scientific literature. Such modifications include correction & republication, retraction and publication of errata. Previous studies evaluating techniques for repairing the literature have primarily focused on the degree to which citation of retracted articles diminishes post-retraction. No similar studies have been performed to evaluate the effectiveness of the

practice of correction and republication. This study evaluates the effectiveness of correction & republication as a technique for repairing the scientific literature. It does so in two ways: First by measuring post-republication citation of invalidated articles and secondly by measuring presentation of information about post-publication modifications at the level of bibliographic information sources as a possible explanation for the phenomenon of post-correction citation.

Appropriate citation requires author awareness of the status of articles; this study first measures author awareness as evinced by citation, then evaluates how often bibliographic information retrieval systems provide information about flawed documents and the existence of republished versions of documents as a possible explanation for post-republication citation. Thus, this study evaluates how often republications have supplanted the articles they were meant to correct by examining the scientific literature in its key roles as source material and professional output. This study considers appropriate citation to be evidence of successful post-publication document correction. In the context of the post republication citation of corrected and republished articles, this study considers appropriate citation to be the referencing of the republished, definitive version of the document pair and inappropriate citation to be the post-correction citation of the repudiated original without concurrent citation of the authoritative republished version.

In the case of flawed original articles, if the retrieved bibliographic information provides information about its own withdrawn status, or includes bibliographic information about the republication (or both), it is considered to be effective at alerting users to its anomalous condition. If neither information regarding the article's status as having been withdrawn nor information about the republished version is provided in the entry, it is considered to not be effective at alerting users to changes in the literature.

In the case of republished articles, if the bibliographic entry retrieved provides information about its status as a republication or provides bibliographic information about the original, (or both), then the entry is considered to be effective at alerting the user to the article's status. Conversely, if neither information about the article being a republication nor information about its counterpart are provided, the entry is not considered effective at alerting users to post-publication changes to the literature.

Assumptions:

This bibliometric study relies on a number of assumptions regarding the literature and the phenomenon of citation:

- It is assumed that an article that has been corrected and republished is perceived as having been completely withdrawn in lieu of the republished

version. This assumption is justified because the act of republication is uncommon and so must be interpreted as the formal endorsement of the subsequent version. Further, NLM also identifies duplicate publications as aberrant literature and so cannot be assumed to be endorsing the two versions of a document, particularly when one has been formally identified as less reliable than the other.

- It is assumed that if an author is aware of both versions he or she will choose to cite the republished version as definitive. This assumption is justified because publication is a formal exercise, the personal stakes of which are very high for the author. Authors are highly motivated to use the best possible resources to produce the optimal intellectual product.

- It is assumed that the act of citation implies relevance to the citing publication and that there is a conceptual link between the two documents that relates them. This assumption is justified by the theoretical works of Garfield and Price, and by research findings, both of which were described in more detail in Chapter 2.

- It is assumed that citation can be treated as evidence of an author's awareness of and use of the cited article.

Limitations

Members of the sample had to fulfill the following criteria:

- The documents had to be indexed in Medline under the publication type "corrected and republished article".
- The article was published in journal that is a part of the Core Clinical Journals subset. Formerly known as AIM-indexed journals, these sources rank among the most influential publications in the biomedical literature.
- The article was published between January 1, 1990 and January 31, 1999.

This limitation allows for considerations of both publication lag and obsolescence.

The study is further limited by the selection of portals used. The study was limited to two high profile services, one public, free service, (PubMed) and one fee-based private service (Web of Science) which were selected based upon their popularity and ubiquity. Though the Web of Science is a fee-based service, it was selected because of its high profile and because most scientists receive support from either universities or industry so access can be considered universal. Further, both resources are designed in such a way that the same experiment can be performed on both systems, allowing for greater equity of results.

The study does not perform a citation context analysis (evaluating the nature of the citation) and is so justified for two reasons: Research findings have confirmed the predictions of theoreticians that negative citation is uncommon and is not perpetuated in the literature in the same manner as positive citation and is

subsequently of limited statistical significance. Thus, negative citation should not have a substantial impact on this evaluation of citation patterns and so a citation analysis to evaluate the nature of the citation (positive or negative, explicit or implicit), is unnecessary. Secondly, it is justified by the twofold limitation that citation context analysis relies on the subjective interpretation and evaluation of references in diverse biomedical sciences, requiring considerable knowledge and expertise in multiple scientific disciplines by the researchers, (of which there must be more than one), to confirm interpretation. These requirements outstrip the abilities of the researcher both numerically and in terms of erudition. Investigation of the nature of post-republication citation may be of value, but it is beyond the scope of this study.

Research Design

A dataset is defined by the research question and how that question is to be answered. To answer the question, a dataset should be described based on the characteristics of the data and analysis that contribute to answering the question. The dataset should be limited to a substantial but manageable group of relevant examples of the phenomenon under study: Desirable data must be defined in terms of how it and its analysis answers the question. Subsequently, a data source & sample must be identified, a sample must be obtained and data must be extracted.

This study is a comparison of citation levels of corrected and republished versions of articles. The comparison is made with the intent of determining if the practice of correction and republication results in reduced citation of invalidated literature. This study also evaluates the degree to which authors are aware of and incorporate corrections into subsequent work. The study treats citation as a proxy for use and assumes the relevance of the cited work to the citing work. Thus, citation is treated as an indication of author awareness and use. Citation data can therefore be exploited to compare the use of related documents.

The study then examines the degree to which prominent sources of bibliographic information pertaining to the biomedical sciences alert users to the status of corrected and republished articles as a possible explanation for continued post-republication citation. This question is intended to determine if a lack of user awareness regarding the status of anomalous articles may be responsible for post-republication citation, as has been suggested by some researchers. To this end, the data provided by bibliographic information retrieval systems are examined for information about other versions of anomalous documents.

Medline is an appropriate target for such a search for a number of reasons: Medline is a huge index (over 15 million entries) of biomedical literature that is heavily used by the research community. Medline is a publicly accessible database that is used by researchers and clinicians alike. Also, since 1991,

Medline has noted the existence of corrected articles and their republished versions using a special publication type known as “corrected and republished article” and has extended indexing of this literature back to 1988. Medline is searchable by publication type, so a sample of all corrected and republished documents can be obtained from the scientific literature without a priori knowledge of their identity or location. Though other repositories of biomedical literature exist, only Medline can be searched using this criterion, allowing for retrieval of this complete and unique sample. A manual search for a sizable document set would not be feasible considering the size of the biomedical literature and the largest sample possible is preferred to a more limited one because of statistical considerations. A solution is found in the selection of the electronic sources of bibliographic information about the biomedical literature.

After the set of corrected and republished documents has been identified and retrieved and the bibliographic information for its members recorded, citation information can be retrieved from the Web of Science's Science Citation Index. Retrieval of information about document citation from SCI requires bibliographic information, (specifically journal title, author name and publication year), all of which can be obtained from the Medline entry for an article. By following the procedures described, the dataset was generated.

Pilot Sample:

The procedure and analyses were tested on an initial sample of six corrected and republished review articles. This cohort was identified as the subset of the total collection of corrected and republished articles published in core clinical journals that were also indexed in Medline under the publication type "review article". This corpus was selected because review articles are particularly influential documents, (and therefore potentially more likely to be cited than non-review articles) and because it represented approximately 10% of the total sample of corrected and republished articles published in Medline Core Clinical Journals between January 1, 1990 and December 31, 2000. Further, the Medline interface provides a special display for this publication type when results are returned, so the initial design of this project presented an obvious sample upon which to work while refining the project.

Question #1.1: ***Is there a difference between average citation levels of original and republished article versions over time?***

Description of data attributes:

A dataset is defined by its research question and how it is to be answered. In the case of the current study the question is one of article use as a measure of correction effectiveness and it is answered via a comparison of citation counts for article versions over time. To perform this comparison, a selection of corrected and republished articles must be obtained. This dataset should be a

representative sample of the clinical literature, the articles in the sample should be recent enough to still be cited in the current research literature, (avoiding the problem of diminishing citation through obsolescence), but must also have been published at least one year after the republication to account for publication lag. The dataset must include citation information for all qualifying documents.

This research question is answered by applying a t-test, a difference of means analysis whose null hypothesis can be stated as: Ho = μ1 = μ2, where μ is the average incidence of an event. In this case, the test determines if there is a difference between the average incidence of citation of original and republished versions of documents. Comparing the average incidence of citation of different document versions shows whether the republication has become the authoritative version of a document as source material because citation suggests author acceptance and use of that version as definitive. Thus, the appropriate data must be extracted from the sample of bibliographic information retrieved from a Medline search for corrected and republished articles and a spreadsheet to contain these data is subsequently prepared.

Question 1.1 - Data retrieval

Bibliographic information for republished articles was obtained by directing a web browser to the PubMed url at http://www.ncbi.nlm.nih.gov/entrez/query.fcgi, accessing the main Medline interface. A click on the “Limits” tab opens a new page, allowing the user to

refine search parameters. In the “Search for” box, the phrase “corrected and republished article” was entered, and in the “Dates” field, the search was limited to 1999/01/01 to 2000/01/01. This restriction of the dataset ensures the currency of the literature while allowing for permeation of the correction into public awareness. In the field labeled “Subsets” the set “Core Clinical Journals” (CCJ) was selected, limiting the search to the clinically relevant group of journals formerly known as the Abridged Index Medicus subset. This option selects high profile journals that are known to have a lower incidence of inappropriate explicit citation of retracted articles than non-CCJ articles. (Budd, Sievert et al 1999) It is hoped that the high quality of citation noted in these Journals for one kind of anomalous literature extends to another. Finally, in the “Type of Article” field, the option “Corrected and republished article” was selected.

After obtaining the articles indexed under the publication type “Corrected and Republished Article” from Medline, the bibliographic information must be extracted. This step is necessary so that citation data for each version can be obtained. Citation data are retrieved based on bibliographic characteristics and due to the frequently nearly identical appearance of original and republished versions of articles, detailed bibliographic information for each article is required.

- Bibliographic information for identification of corrected & republished articles:
    - Author
    - Title

- Journal
- Date
- Volume & page information

- Citation information for corrected & republished articles:
  - Total number of times cited
  - Number of times cited <12 months post republication
  - Number of times cited 1-4 years post-republication
  - Number of times cited 5-8 years post-republication
  - Number of times cited 9-12 years post-republication
  - Number of times cited 12+ years post-republication

For each republished article retrieved in the Medline search described in Step 1, the following procedure was followed. On the page of search results generated by Step 1, the field containing the article's author's names was selected by mouse-click. This action results in the retrieval of a new page containing bibliographic information about the republication. The information described above is extracted. The heading “Corrected and Republished From” is subsequently selected, resulting in the display of a page containing bibliographic information about the original article, which is also recorded.

For each article in the dataset obtained by the Medline search, the following procedure was followed:

From the Web of Science webpage the Science Citation Index is accessed and the option Cited Ref Search is selected. (This opens a new page, the Web of Science Cited Reference Search page.) Bibliographic information for each article in the set is retrieved using the following search limits: The last name and first initial, followed by an asterisk, of the first author of the article, the abbreviated journal title in which the article appeared in the "Cited Work" field (using the Thomson ISI list of journal abbreviations), and the year the article was published.

On the page retrieved when the preceding information is submitted, the matching bibliographic entry is selected, and the total number of cited to the article is noted on the spreadsheet. Finally, the "Finish Search" button is clicked. Using the bibliographic information displayed and the publication information on the spreadsheet, the amount of time between publication of the citing document and the date the republication came into print is noted.

Question #1.2: ***How many documents that contain a citation to the original version of a corrected and republished article also contain a citation to the republished version of the article?***

Description of data attributes:

Question #1.2 contributes to the primary objective of this study by measuring inappropriate citation of flawed literature. This question is answered by comparing the number of post-republication articles that cite the original only, the republication only and both versions. Co-citation is a strong indicator of author awareness of both versions and suggests author awareness of the anomalous nature of the article pair. Conversely, citation of only the flawed document suggests that the citing author is unaware of the existence of a more authoritative version of the article. Information gathered for Question 1.2 complements the data gathered in the previous portion of the study by providing another unobtrusive quantitative measure of the effectiveness of correction and republication.

Corrected and retracted articles were identified and their bibliographic information obtained using Medline. Citation information for each article was retrieved from the Web of Science's Science Citation Index. The reasoning behind the selection of these sources and the procedures for retrieving the bibliographic data were described in the apologia for Question 1.1. A primary purpose of the Science Citation Index is to allow users to identify subsequent articles that cite a particular published work: the identity of articles that cite documents in the sample can be established by extending the search initiated in Question 1.1. These results can then be used as fodder for a subsequent SCI

search to obtain the bibliographies of citing articles. By following the procedure described, the desired data was obtained.

Research question 1.2 tests the following null hypothesis:

Ho: Articles that cite the original version post-republication cite the republished version at the same rate.

The dataset is defined by the question and how it is to be answered; in this case, the question is one of article co-citation as a measure of correction efficacy. It is to be answered by calculating the incidence of co-citation (the phenomenon defined for the purposes of this study as the inclusion of both members of the anomalous article pair in the bibliography of a citing article) of corrected and republished articles. To perform this investigation, the same sample of corrected and republished articles retrieved in the first part of the study was used.

Question 1.2 - Data retrieval

The procedure required to extract data for this evaluation is more complex than that obtained in the previous section, which simply compared the incidence of post republication citation of each article in the sample. In this case, the list of citing articles is obtained by performing a Web of Science cited reference search for each member of the article pair and comparing the results for common entries. The bibliographies of articles found in both lists of citing articles were

examined to confirm that both versions of the corrected and republished article are indeed listed. Thus, for every member of the sample, the number of articles that co-cite both members of the anomalous pair was noted.

Question 2: ***How often do bibliographic resources present information regarding the existence of republished versions of articles?***

The second research question examines a key factor to appropriate citation, the frequency with which users are provided with information about post-publication changes to the literature. It has been suggested that inappropriate citation is attributable to author ignorance of the anomalous nature of the document in question. Question #2 determines how often bibliographic databases provide users with information regarding the status of an article as having been the object of post-publication modification. This research question assumes that authors will choose to use the best (i.e. the most recent & authoritative and thus reputable & persuasive) source material available when designing and sharing research. Consequently, author awareness of the status of anomalous literature can be indirectly measured by examining the bibliographic records for that literature.

The Medline and Web of Science databases are both very large collections of bibliographic information regarding scientific literature. Both collections are very commonly used by research professionals when searching

scholarly literature. The Web of Science offers a standard bibliographic search function similar to that offered by Medline's PubMed interface. This feature is reached on the Web of Science website by selecting the "General Search" option rather than the "Cited Reference Search" option. Thus, the same kind of search on the same dataset can be performed on both databases, using the article's title and first author's last name as search terms, simulating user ignorance of the status of these articles as being unusual.

Description of data attributes:

The purpose of this part of the study is to determine the extent to which authors are provided with information about the nature of anomalous articles as a possible explanation for inappropriate citation. Question #2 determines the frequency with which bibliographic entries for corrected and republished articles provide information about the existence of the other version or information about the anomalous status of the article. The data collected to answer this question are obtained by scrutinizing the bibliographic citations for anomalous literature. To this end, searches were performed in a manner approximating that of a user; articles were retrieved using the title and first author's last name as search fodder, assuming ignorance of the status of the document. The presence or absence of annotation alerting users that an article has been changed (or constitutes a change), was recorded and the number of articles that direct users to the other version were noted.

Question 2 – Data Retrieval

Question #2 was first addressed by examining the bibliographic records of the Medline and Web of Science databases for each article in the sample. Records were retrieved using the last name of the first author of the article and the article's title (e.g. "Johnson" and "Flexible sigmoidoscopy screening for colorectal cancer"). Any information in the record indicating that the article was a correction, had been corrected, or was in any way anomalous was accepted as a valid author alert. The examination assumed a basic but thorough search behavior; if an entry was hyperlinked to a more complete record, the link was followed and the more complete record scrutinized.

Conclusion:

The data collected for this study describe the degree to which citation of original, invalidated articles continues after correction and republication and the extent to which citation of invalidated literature is appropriate. This research assays the effectiveness of correction and republication by examining the extent to which citation of republished versions of articles has supplanted citation of originals. It is performed by comparing average incidences of citation of original and republished versions of documents at multi-year intervals and by examining incidence of simultaneous citation of corrected and republished article pairs. The research subsequently examines the extent to which users are informed of the

status of anomalous articles as a possible explanation for post-republication citation patterns.

Chapter 4: Analysis and Results

Introduction:

This chapter presents descriptions of bibliometric analyses performed on data collected as described in Chapter 3. For each question, this chapter first describes the method and significance of the analysis undertaken and then presents and describes the relevant results. Results are summarized graphically and numerically and are explained in the context of the stated hypotheses. Data are presented in their entirety in Appendix [A], statistical analysis of the data is presented in Appendix [B].

Statistics:

Software:

Statistical analysis was performed using SPSS for Students v9.0.

Data analysis:

The raw data was entered in a spreadsheet as described in chapter 3. Data was then tabulated and outliers were removed. Outliers fell into three categories:

- Articles cited much more frequently than the norm. Six of the retrieved articles had more than 100 cites to the article pair. Considering that the average

lifetime citation rate of articles in the dataset (excluding this group) is 24 citations over twelve years, these samples seemed to have abnormally high citation rates.

- Articles pairs that received no citations over their lifetime. Four articles fell into this group.

- Articles whose republication's volume and page number were indistinguishable from that of the original, making it impossible to determine which version a citing author intended to reference. In these cases, the Web of Science Cited Reference Search attributes all citations to the original and none to the republication. These entries do not measure citations to republished versions of articles and must thus be eliminated. Five examples of this type article were found in the sample.

Eliminating these articles reduced the sample to 47 entries.

For articles that had been corrected and republished between 1990 and 2000, the following information regarding post-correction citation was collected.

	n	Minimum Cites	Maximum Cites	Average Cites	Std. Deviation
Republication	47	0	61	12.72	14.48
Original	47	0	60	11.70	14.56

Table 1: Incidence of citation of article versions

The primary research question, *(Is the practice of correction and republication of biomedical literature effective?)* is addressed by asking the following questions:

Question 1.1: ***Is there a difference between average citation levels of original and republished article versions over time?***

Question 1.2: ***How many documents that contain a citation to the original version of a corrected and republished article also contain a citation to the republished version of the article?***

Question 1.1 asks if there is a difference in citation levels of different versions of articles after republication. The null hypothesis for Question 1.1 is expressed as:

Ho: μ1 – μ2 = 0

(μ1 and μ2 are the average incidence of citation for corrected and republished articles, respectively.)

The null hypothesis can be stated as "There is no difference in the average incidence of citation among original and republished versions of corrected article pairs."

The first question is addressed by applying the technique known as citation analysis. The analysis was performed on a sample comprised of bibliographic and citation information for documents published between 1990 and

2000 that are also indexed in Medline with the publication type “Corrected & Republished Articles” and are published in the high profile document set known as “Core Clinical Journals”. These articles were identified and retrieved from Medline as described in Chapter 3 and then used to obtain citation data from the ISI Science Citation Index via the Web of Science portal. Citing articles included in the sample were published not less than one year post-republication. This one year publication lag is intended to account for potential legitimate citations that may have been in press at the time that the republication was released, thus carrying a post-republication citation date while legitimately citing the original as valid. A summary of tabulated data and the categories required to perform the statistical analysis are presented in Appendix [B].

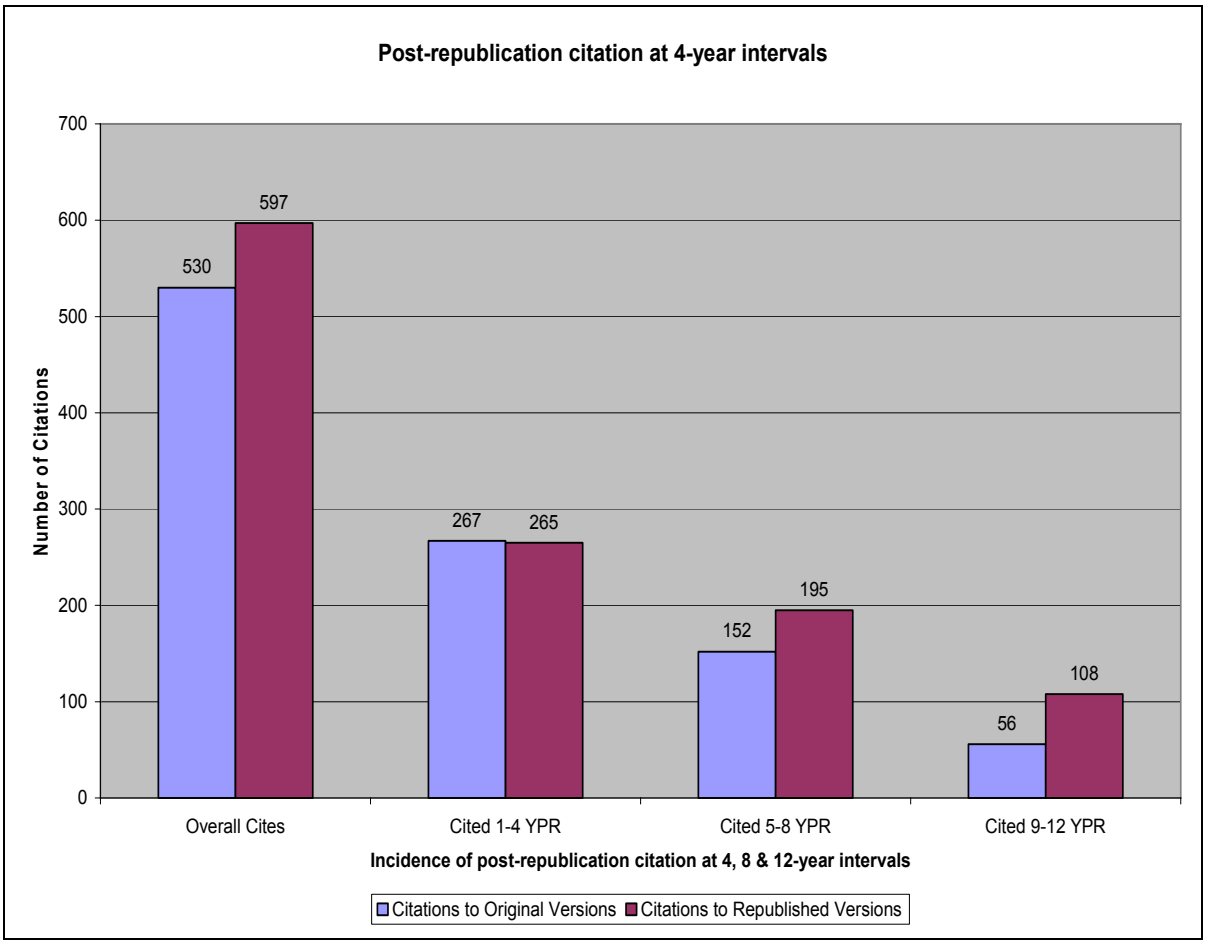

Figure 1: Citations to article versions over time

Initial comparison of citation levels of article versions shows that the original and republication are cited at similar levels. When the incidence of citation of article versions is compared at 4-year intervals, it appears that after the first interval, citations to the republication exceed that of those to original articles. **(Figure 1)**

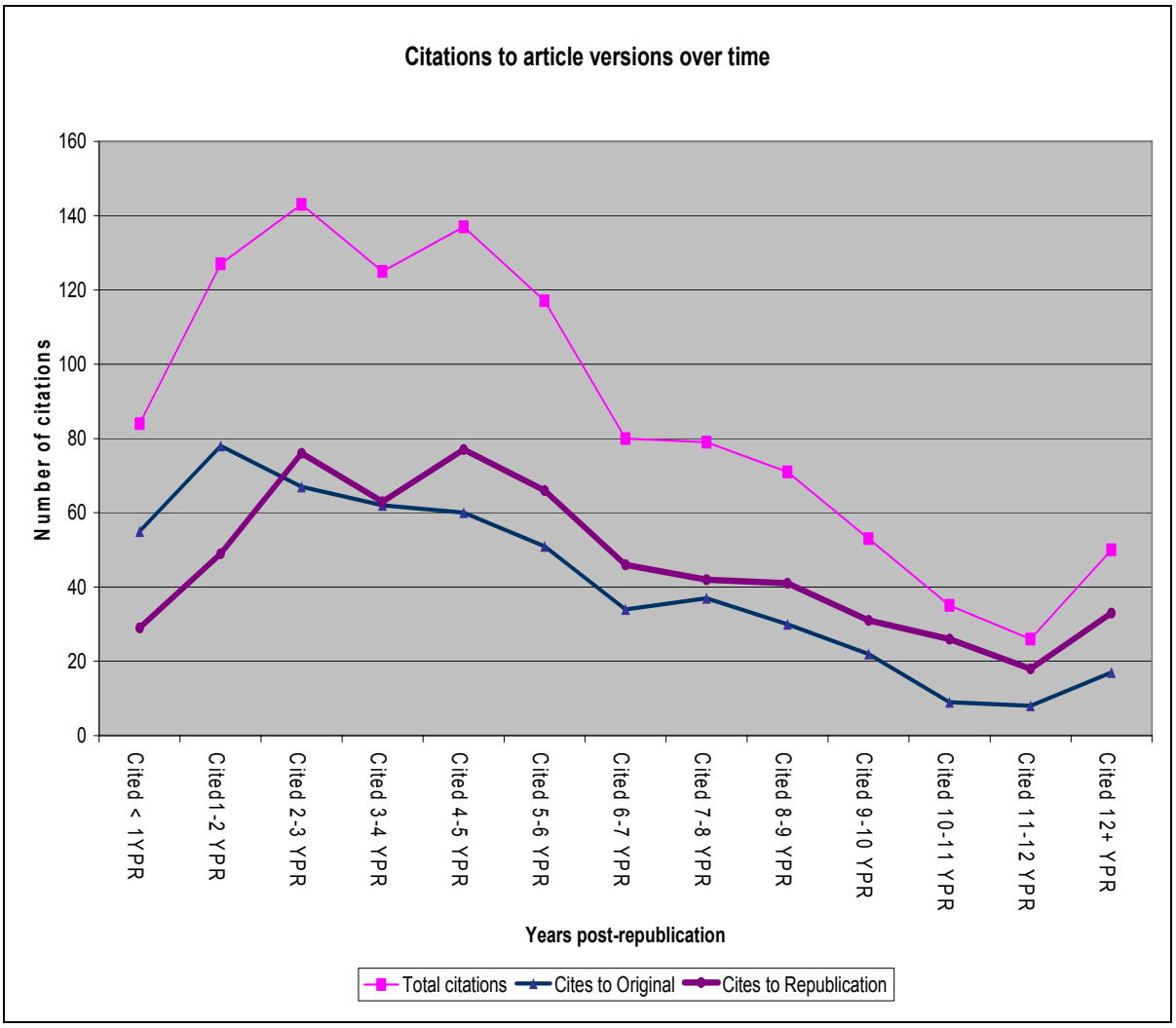

Figure 2: Citation over time

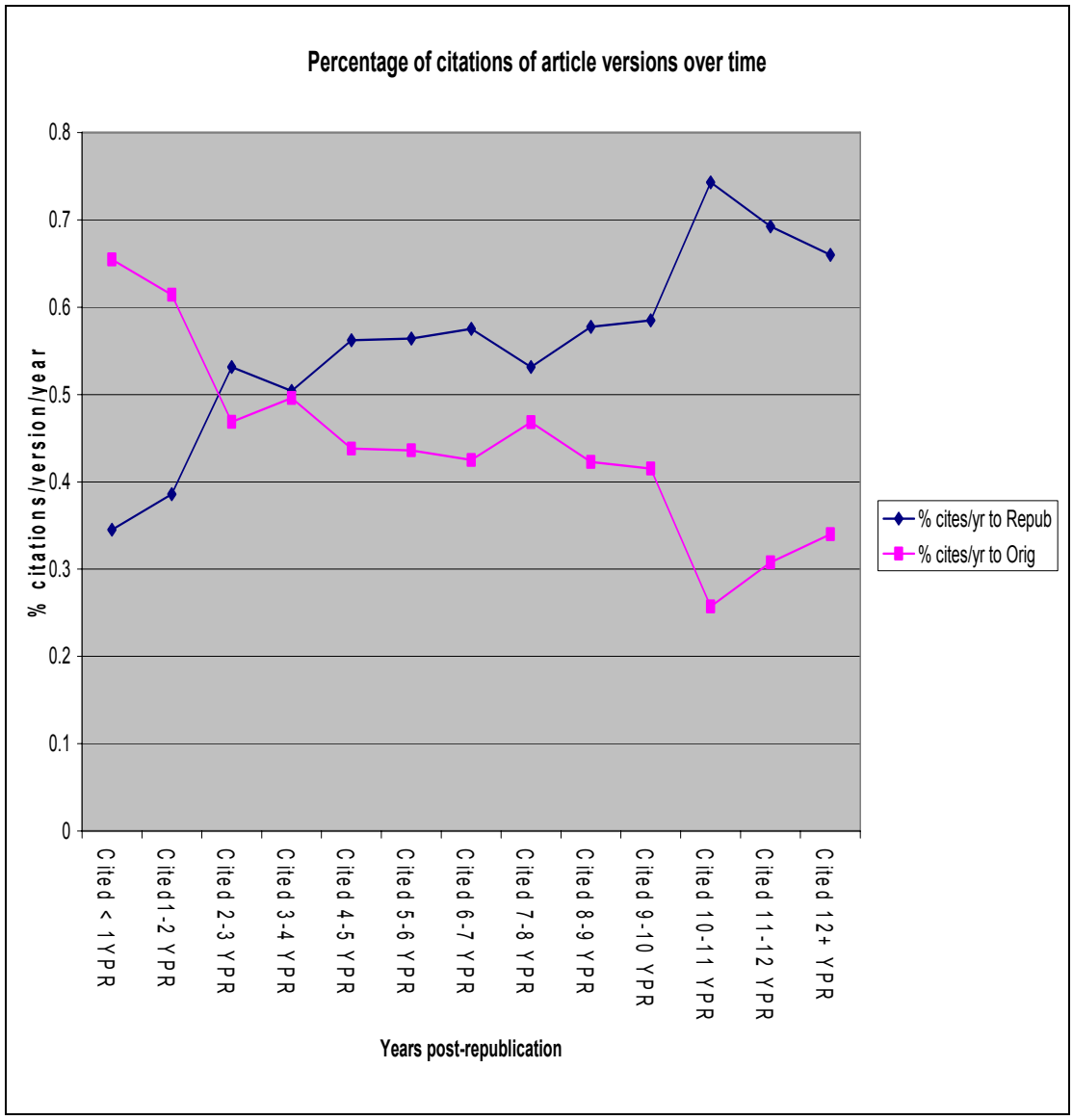

Figure 3: Average citation over time

Plotting the incidence of citation of versions of members of article pairs over a period of twelve years confirms the results indicated by the histographic comparison shown in Figure 1. After the third year post-republication, the

incidence of citation of republications is higher than that of originals. **(Figures 2 & 3)**

The data collected allow the null hypothesis to be tested using the statistical method known as a t-test. The t-test allows the researcher to measure a difference between two averages. This dataset is comprised of bibliographic information for a group of documents that are made up of pairs of related articles. Because the articles being compared are related and because the comparison measures for a treatment effect on both article versions, the data are described in statistical language as *paired* (as opposed to independent), and so the eponymous t-test appropriate to this type of data is applied. The paired t-test compares the difference in average citation rates of republished and original versions of articles (expressed as $\mu 1 - \mu 2$) and the standard deviation of the sample (s_d).

This statistical test makes three assumptions, all of which are fulfilled by the dataset:

- The samples are paired.

    - The samples are pairs of articles

- The *n* sample differences can be viewed as a random sample from the population.

- The articles are members of the Medline database with no common traits other than having been corrected & republished

- The number of the sample is large, (typically greater than 30).

- The sample size is over 30.

The t-test relies on the determination of a *P value*, (also known as the observed significance level) which is defined as:"a measure of inconsistency between the hypothesized value for a population characteristic and the observed sample. It is the probability, assuming that Ho is true, of obtaining a test statistic at least as inconsistent with Ho as what actually resulted" (Devore 2001) (Devore, p.365) The P-value for a t-test is obtained by consulting a t-curve chart (Devore, p382) and determining the area to the right or left of the calculated t-value, depending on whether the test is for a value of μ of greater or less than the hypothesized value (respectively). In cases in which the researcher simply wants to test between Ho: μ = value and Ha: μ != value, the P-value is calculated by doubling the area under the curve to the right or left of the calculated t-value. In practical terms, a low P-value indicates that the null hypothesis should be rejected, (because a low P-value indicates a low probability that the same results will be obtained given the validity of Ho), and a high P-value should conversely contraindicate rejection. If a P-value is less than the selected significance level, (typically set at 0.1, 0.05 or 0.01), rejection of the null hypothesis is typically recommended. The significance level (denoted as α=0.01, or simply α) is the

probability of mistakenly rejecting the null hypothesis. (This mistake is also known as a Type 1 error.) If the P-value is less than the significance level, then it can be said that the probability of incorrectly rejecting the null hypothesis because the sample is not consistent with what was predicted by the null hypothesis is less than the significance level. In other words, if P-value is less than 0.05, the null hypothesis can be rejected with little fear that the decision is made based upon non-representative data.

The paired t-test for all post republication citations to articles in the data set is summarized below:

	Overall	1-4 YPR	5-8 YPR	9-12 YPR
correlation	.536	.563	.322	.533
s_d	12.93	6.69	5.61	4.80
t	1.128	-0.044	1.117	1.639
df	46	46	46	46
P-value	0.139	0.460	0.139	0.059
α	0.05	0.05	0.05	0.05
Ho	Do not reject	Do not reject	Do not reject	Do not reject
α	0.10	0.10	0.10	0.10
Ho	Do not reject	Do not reject	Do not reject	Reject

Table 2: C&R citation t-test

The t-test does not detect a statistically significant difference between the average incidence of citation of original and republished versions of articles when

the article versions were compared in a single group. However, a comparison of versions over 4-year intervals shows a difference in the citation levels of corrected and republished article pairs. A t-test with $\alpha = 10\%$ shows a difference between the versions at the 8-12 year interval. Again, while a bulk comparison does not suggest that the republished versions of article pairs are preferred as a source among citing authors, a more nuanced approach shows that over time, the republications are cited more frequently than the originals.

Q1.2 Co-citation analysis

The second part of question #1, "*How many documents that contain a citation to the original version of a corrected and republished article also contain a citation to the republished version of the article?"* evaluates how often authors that cite original, flawed documents do so appropriately, as demonstrated by concurrent citation of the more recent, corrected version. By measuring the extent of co-citation, the analysis provides another measure of the extent to which one document has replaced another as authoritative among authors of subsequent biomedical literature.

The practice of studying scholarly literature using mutual citation as the phenomenon of interest is known as co-citation analysis. This technique is typically used to determine relatedness among objects of study by making the justifiable assumption that mutual citation implies relatedness. However, in this

research, the evaluation of the phenomenon of co-citation is applied in a novel way. In this study, the technique assays author awareness of republications by measuring how often documents that cite one version of an article pair also cite the other. Citation of both versions of the article indicates awareness of the nature of the document pair as anomalous. Thus, co-citation is treated as evidence of user awareness of the flawed nature of the original and evidence of successful treatment effect of the correction. The indication of user awareness of literary anomalies through co-citation is predicated on the assumption that authors choose to cite the best material available to them to make their work as robust as possible. Citation demonstrates author awareness of and use of the literature, so inclusion of both versions strongly suggests user awareness of the flawed nature of the original. Conversely, given the generally positive nature of the literary reference, citation of the original and absence of simultaneous citation of the republication suggests author ignorance of the status of the original document as having been invalidated and corrected. Consequently, this study treats the phenomenon of co-citation as evidence of (appropriate) negative citation and as evidence of the effectiveness of the phenomenon of correction and republication. Republication is intended to direct author behavior by correcting a flaw in the literature. This part of the study measured the effectiveness of republication by regarding co-citation as evidence of successful correction.

Articles examined in this part of the study must adhere to certain additional criteria: to be included in the analysis the original article must have been cited at some point more than one year post-republication. In cases in which the original article has only been cited once, the citing article must not be the republication. Data collected for this portion of the study are categorical, consisting of a tally for the incidence of co-citation of document pairs. Data were collected though bibliographic analysis, examining documents that cited an original and that also cited the republished version, and subsequently calculating the percentage of those that did. Citations from the republication to the original were not counted among the pool of potentially co-citing articles because they cannot reference themselves and thus are not candidates for co-citation. 21 republications cite the original version of the article and so are not candidates for co-citation. Removing these articles from the sample yields a total of 1100 citing articles that potentially contain bibliographic entries for both versions.

Number of articles citing either version: 1106
Number of articles that cite both versions: 13
Percentage of articles that cite both versions: 13/1106 = 0.0118 = 1.18%

The data suggest that co-citation of original and republications occurs at a rate of approximately 1% among post republication citations. Authors that cite

originals after they have been replaced with more authoritative versions rarely indicate through co-citation that they are aware of the existence of the definitive version. Co-citation analysis shows little indication that authors are knowingly citing invalidated literature. The data indicate that citation of flawed articles occurs at a rate nearly equal to that of corrected versions and that there is little indication that authors that cite flawed literature do so knowingly.

Question 2: Information retrieval analysis

The second research question determines if there is a difference between Medline & Web of Science in their presentation of information directing searchers to authoritative versions.

Question 2: ***How often do bibliographic resources present information regarding the existence of republished versions of articles?***

To answer this question, the following must be ascertained:
How often does the bibliographic information for the original document contain information alerting the user to the republication in Medline and Web of Science?

The purpose of this analysis is to determine how often prominent bibliographic sources direct users to the most authoritative versions of articles.

The degree to which electronic bibliographic resources direct users to authoritative works is evaluated as a possible explanation for inappropriate citation. It has long been assumed that electronic information retrieval systems are more effective at alerting users to post-publication changes to the literature than traditional printed resources. Bibliographic databases are an important resource for researchers; failure of these systems to direct users to later, authoritative article versions may contribute to continued author use and citation of invalidated literature. The main bibliographic entry for each article version presented on Medline and Web of Science for corrected articles was examined for information directing the searcher to the definitive, republished version of an article. It is important to note that this part of the study examines the main entry for each article; only information included on those pages was considered. In some cases, title searches yielded multiple entries. It cannot be assumed that a searcher would carefully scrutinize each entry when pursuing a particular document. Thus, only the main bibliographic entry and not the linking entry were considered in this evaluation.

The data show that when the title of a corrected article is submitted to the selected search engines and the main bibliographic entry for each article is examined, Medline provides information about the republished version 70% of the time, while Web of Science does so at a rate of only 4%. Clearly there is

considerable disparity between the results provided by these two sources of bibliographic information.

	Medline entry points to counterpart	WoS entry points to counterpart
Article pairs	47	47
Republication	47 (100%)	28 (60%)
Original	33 (70%)	2 (4.3%)

Table 3: Information about anomalous articles

Summary of Results:

Question 1.1: ***Is there a difference between average citation levels of original and republished article versions over time?***

Results of question 1.1 indicate that post-correction, flawed articles continue to be cited at a rate nearly equal to that of the republished version. Citations to republications do exceed those to originals in the years post-republication, however a t-test indicates that the effect is not statistically significant until 8-12 years after the correction has been published.

Question 1.2: ***How many documents that contain a citation to the original version of a corrected and republished article also contain a citation to the republished version of the article?***

Data gathered to answer question 1.2 indicate that co-citation of original and republished articles is very uncommon, occurring among only 1% of post-republication citations.

Question 2: ***How often do bibliographic resources present information regarding the existence of republished versions of articles?***

Bibliographic information sources show considerable variability in their presentation of information regarding the status of anomalous articles in the dataset. Medline provides information about the corrected version in 70% of main bibliographic entries for invalidated original articles, while Web of Science

provides that information only 4% of the time for the same group of articles. Further, while every Medline entry for a republished article indicated that it was a republication, only 60% of Web of Science entries for the same articles contained the same information.

Chapter 5: Conclusions

This research is intended to determine if corrections to the biomedical literature are effective. The study compares the citation levels of versions of corrected and republished literature in subsequent research and measures how often prominent sources of bibliographic information direct users to authoritative versions as a possible explanation for continued erroneous citation. The data required to perform these analyses were gathered as described in Chapter 3 and were sorted and analyzed as described in Chapter 4. The significance of the results are be considered in the context of antecedent research and methods and with regard to the assumptions and limitations of this study and how future work may both confirm and expand the findings of this research. This chapter also considers how this research informs the scientific community in general and the biomedical and information science communities in particular.

Contextualizing the results

This study is similar to previous bibliometric studies insofar as it measures the degree to which invalidated versions of documents are referenced by authors in subsequent publications. Such studies typically measure the incidence of post-invalidation citation, in some cases comparing the citation levels of the selected articles to another group, either a control group of normal articles or to pre-

withdrawal citation levels. This research differs from previous studies in at least two important ways: The documents compared are nearly identical pairs of articles, (each having the same title and first author), and the citation levels of members of the pairs are being compared to each other rather than to themselves or a control.

Pfeifer et al compared the incidence of citation of retracted articles to control articles over a decade, extrapolating a cumulation citation curve that described a gradual diminution in citation of retracted articles. Wright utilized the statistical t-test to determine whether retraction depresses subsequent citation, finding a difference in the citation levels of selected articles between the two-year periods before and after retraction. This study compares citation levels of the different versions, using a t-test to determine if there is a difference between them over time.

Pfeiffer et al suggested in 1990 that a possible explanation for continued inappropriate citation was lack of author awareness of the status of the document as having been invalidated. Since publication of that study, the utilization of electronic literature databases as sources of bibliographic data has grown tremendously. Given the continued phenomenon of post-republication citation of original versions of articles, it is reasonable to test Pfeiffer's assertion by measuring the extent to which two prominent sources of bibliographic information present information about the definitive members of article pairs.

An example of a study of the extent to which entries for anomalous articles provide information about subsequent versions of articles was published by Poworoznek in a 2003 JASIST study that examines the degree of linkage between originals and corrigenda in electronic versions of physical science journals. This study emulates Poworoznek's study in that it evaluates online sources for information about definitive versions of articles.

A major assumption of this study is that the sources of bibliographic information, (Web of Science and Medline) are common sources of information for users. This assumption seems justified considering the other information resources available to users of the biomedical literature, (a group that is almost by definition not comprised of information professionals). Apart from the pair of bibliographic databases used in this study, users have two other obvious information sources, print resources and other online resources. Print resources are assumed to be less efficient than electronic ones for information retrieval, so use of electronic resources is assumed to be preferred by authors, particularly considering that most scientists are associated with technologically advanced research facilities, so even local print collections are very likely to be indexed electronically and connected to external resources. Alternatively, authors may be using other tools for the task of information retrieval, searching other databases than those exploited in this study. This study is focused on the biomedical research literature which encompasses a broad range of subjects. Specialized databases may exist that would contribute to this type of study, however the size

of the Medline database and the consistency of its indexing policies make it the most attractive target for study. Further, Medline receives over 400 million search queries per year, suggesting that it is a very commonly used resource. The EMBASE and SCOPUS databases might be appropriate sources of bibliographic information for a confirmatory study. Resources covering a broader range of subjects such as Lexis-Nexis and the Dialog system represent alternatives for authors, but have their own limitations. For example, Dialog (and other systems) are less well-known outside the community of information science professionals, and often require training and charge for their services. These factors are likely to make the large systems that are commonly used among information professionals less appealing to life scientists and health professionals than a free service that is specifically focused on the biomedical literature such as those used in this study.

Interpretation & Significance of Results

Question 1:

The main question of this study compares the incidence of citation of each version of the article to determine if the practice of correction and republication is an effective mechanism for replacing a flawed document with a corrected one in two ways. First, the study tests whether republications are cited more frequently than originals, comparing version's citation levels to determine if the republished

version increases in its level of citedness relative to the original version of the article over time.

Citation of original and republished versions of articles occurs at nearly equal levels. Citation of republications is slightly more common that that of original versions, 53% of post-republication citations to an article are to the republished version, 47% to the original. Histographic analysis shows that republications seem to be preferentially cited over originals after the third year post-republication. Examination of the relative citation levels of versions at 4-year intervals indicates that republications are preferentially cited by authors after four years post-republication. However, a t-test comparing citation of corrected and republished versions detects no difference in their citation levels overall. A t-test of corrected and republished versions at 4-year intervals detects a difference in the 8-12 year interval with an alpha of 0.10. These results suggest that correction and republication is not effective at preventing post-correction citation of flawed biomedical literature.

A superficial examination of the results would suggest that republications are cited more frequently than originals, that is, that there is a treatment effect from the practice of correction & republication. However, a more nuanced analysis shows that there is indeed no statistically significant difference between version citation levels until 8-12 years post-republication. These data indicate that as documents age, the republished versions of the articles are cited with

more frequency than originals, however the effect is not strong. Though the practice of correction and republication is somewhat effective, it does not prevent the inappropriate citation of documents that have been identified as containing errors.

The study then determined the frequency of the phenomenon of co-citation. The purpose of this analysis is not to determine the relatedness of the documents based on co-citation as is traditional in bibliometric studies, but rather to determine how often post-retraction citation of original articles is accompanied by concomitant citation of the republished, authoritative version. This evaluation is significant not only because it is a further measure of the extent of inappropriate citation of invalidated articles, but also because co-citation (in this circumstance) strongly suggests author awareness of the status of the original and the existence of the republished version. Co-citation of corrected and republished article pairs is treated as an indirect measure of negative citation, the measurement of which is a novel application of co-citation analysis. While it is known that negative citation exists, it is assumed to be uncommon and difficult to measure, traditionally requiring laborious citation context analysis by multiple qualified evaluators.

Results show that co-citation of corrected and republished article versions account for only 1% of post-republication citations. This suggests that the

phenomenon of negative citation of flawed originals is very limited and that inappropriate citation of flawed literature is common.

It is apparent that the phenomenon of co-citation does not occur with a significant degree of frequency. This result also suggests that if the assumption that co-citation implies negative citation of the original is valid, the phenomenon is very uncommon. Indeed, this level of negative citation is lower than the levels of negative citation observed by other researchers. (Budd et al observed an 87% positive citation rate, and Wright observed a 10% explicit negative citation rate.) This is remarkable, because this measure suggests that the incidence of negative citation of these known flawed documents is actually lower than that for normal, untainted articles. The implications of this continued citation of erroneous literature are that authors show little indication of awareness of the later, authoritative version of these articles, (as evinced by co-citation of the republished version), suggesting that flawed information continues to be used and propagated in the biomedical literature.

Question 2:

The second part of this study examines the output of bibliographic databases of scientific literature to determine the frequency with which entries for articles direct the searcher to the republished, authoritative version. The impetus for this part of the study is the suggestion of some researchers that the phenomenon of citation of invalidated literature is attributable to ignorance of the

status of the document on the part of the citing author. Given the observed phenomenon of citation of original, flawed articles, (and the nature of the data collected in Chapter 3), it is reasonable to determine to what extent the information sources provide the user with the appropriate information.

Corrected and republished articles are remarkable in that the documents comprising the pairs are nearly identical, and in all cases in this study the articles have the same title and first author. Thus, a search for these two key identifying attributes may return information about either or both of these articles. A user is not likely to be aware a priori that the document whose record is retrieved is one that has been identified as being anomalous. This part of the study measures the frequency with which a search for each of the identified articles provides the searcher with information about the later version of the article. If the bibliographic information sources consistently provide the searcher with information about the status of these articles, then it is not reasonable to say that the phenomenon of citation of invalidated articles is due to lack of information provided by these electronic resources. Considering the prominence of electronic resources as tools for literature retrieval, if republications are identified by these resources, then the continued use of flawed literature is likely not attributable to lack of information presented to the user.

Results of this part of the study indicate that bibliographic information sources show considerable variability in their presentation of information regarding the status of anomalous articles in the dataset. Medline provides information about

the corrected version in 70% of main bibliographic entries for invalidated original articles, while Web of Science provides that information only 4% of the time for the same group of articles. Further, while every Medline entry for a republished article indicated that it was a republication, only 72% of Web of Science entries for the same articles contained the same information. The data suggest that Medline is considerably better than Web of Science about alerting users to the existence of republications, however it also fails to do so with a frequency of nearly 30%. Thus, it appears that the major repositories of bibliographic information for biomedical research literature do not consistently provide users with the best information possible. The scholarly community would surely benefit were measures to alert users about anomalous literature to be made more robust.

Conclusions & future directions:

The data support a number of conclusions regarding the effectiveness of correction and republication. Primarily, it is apparent that correction and republication does not eliminate citation to flawed biomedical literature. Results suggest that authors cite flawed literature at rate nearly equal to that of republished versions in the decade after republication. However, the data from these inquiries suggest that while citation of invalidated literature is far too common, the republished version does appear to gradually replace the original

as the authoritative source among citing authors. Further, the phenomenon of co-citation is extremely uncommon. If co-citation of article pairs indicates author awareness of the status of invalidated articles, then author awareness of post-publication modifications to the literature is very low. The results suggest that authors have difficulty distinguishing between corrected and republished article versions.

As a possible explanation for the phenomenon of continued citation of invalidated literature, an information retrieval experiment involving two prominent sources of bibliographic information was performed. Results demonstrate that bibliographic information sources regarding biomedical literature vary widely in their presentation of information regarding the status of invalidated literature. Main bibliographic entries in Medline direct the searcher to republished versions of articles only 70% of the time, and the main bibliographic entries for corrected articles in Web of Science provided information about the anomalous status of the original or the existence of the republication in only 2 of 47 cases. The suggestion that erroneous citation behavior is attributable to author ignorance of the status of articles cannot be rejected from the standpoint of information sources in light of this study. Clearly, a more effective system to inform users about invalidated literature would be of use to the scientific community.

Citation of invalidated literature occurs at a rate nearly that of valid literature. Statistical analysis indicates that republications may replace originals

as authoritative over time, but the process is slow. Thus, flawed literature is being cited, (and thus presumably used), by authors with great frequency. The practice of correction and republication is very slow and not strongly effective at reducing citation of flawed literature. In an era of instant delivery of information from many sources, it is incumbent upon the providers of information to provide the best possible information to users at the cutting edge of their research fields. Failure to do so not only may have negative human health impacts, it also corrodes the reputability of the scientific record, which must be maintained at the highest levels in order to ensure the robustness of modern research in all fields of study. The derivative nature of science assumes and utterly relies on the accuracy of the scientific record. The assumption that each article can be individually validated allows researchers to be confident that the accumulated literature for any given topic is reliable. If the assumption of the validity of the scientific record can be challenged, science is undermined at its most fundamental level.

The research indicates that continued citation of invalidated literature is clearly an ongoing problem. Prevention of the phenomenon of erroneous citation is the responsibility of all members of the scientific community, authors, publishers and indexers. The responsibility of authors is to use the best information available when developing and explaining research and the quality of the material cited is ultimately the responsibility of the citing author. However, author vigilance is moderated by the resources and tools available. Further, the

assertion made by one author that researchers have difficulty identifying flawed literature after it has passed editorial review seems to be confirmed. Thus, while it is incumbent upon the author to ensure the quality of his resources, the task is largely mediated by external electronic resources and tools, the quality of which can greatly affect the effectiveness of the author's exertions.

The publication of corrections and alerts regarding those corrections is one of the roles of the academic publisher. Traditionally, correction and republication involves the publication of an updated version of an article that has been identified as containing erroneous literature. Such document is accompanied by a notification of publication of the correction, a public alert that the original article has been invalidated and that the newer version is now authoritative. This practice was inefficient; author awareness of the post-publication modification relied upon the user to examine subsequent print indexes for post-publication changes to any article they cite. The development of electronic indexes was expected to greatly improve the ability of authors to find the most current and reputable information for their own research.

The identification and indexing of the scientific literature is the province of a number of providers of bibliographic information. As the body of scholarly literature has grown, such providers have become very important tools for researchers. The advent of electronic bibliographic resources was expected to make the task of identifying invalidated literature easier. It cannot be denied that

identification and retrieval of literature based upon any peculiarity is greatly enhanced by application of electronic indexing and retrieval strategies. However, as the utility and popularity of these resources has increased, so has the responsibility of providers of such tools to provide the most reliable source material. Failure to do so not only undermines the authority of the information providers but also damages the quality and credibility of research based on that information. Such an outcome is dangerous to individuals and to the community of science in general.

Clearly, responsibility for continued use of flawed literature in derivative works is less important than the fact that the phenomenon exists at all. Further it is clear that booth authors and information providers have a role to play in preventing the use of flawed biomedical literature in research. The author has a responsibility to ensure that they are using the most up-to-date resources possible and to ensure that they are valid. The information provider has a significant role in providing the user with such material and in alerting the user when a literary artifact is in some way anomalous. Greater exertion on the part of both parties would work to reduce this phenomenon and improve the quality of modern science.

Thus, it is apparent that a tool that helps both authors and indexers more effectively manage anomalous literature would be beneficial. The need for such a tool suggests an obvious avenue for continued research. An information

management tool that compared the bibliographies of works to an index of anomalous literature would be a contribution from the information science community that would be of benefit to the entire community of science. Further, this research could be extended in a variety of other ways. A context analysis of articles that co-cite corrected and republished articles would be useful for determining if co-citation of anomalous literature is indeed an indicator of negative citation. Subsequent work could also examine the relative citation levels of anomalous literature to that of work that has not been modified post-publication to ascertain if republication diminished citation of articles relative to normal literature. Another line of inquiry might examine the relative level of citation of anomalous literature that exists in a full text form online versus that which does not. Examination of results indicates that some republications are cited more heavily than others, a better understanding of the characteristics (e.g. journal or author eminence) that influence this effect would be useful in improving the efficacy of the practice of correction and republication. Ultimately, future research should be directed at the problem of making post-publication changes to the literature more effective and at diminishing the erroneous citation of invalidated literature.

Cited Works:

Atlas, M. C. (2004). "Retraction policies of high-impact biomedical journals." J Med Libr Assoc **92**(2): 242-50.

Baker, D. (1990). "Citation Analysis: A Methodological Review." Social Work Research & Abstracts **26**(3): 3.

Becher, T. (1989). Academic tribes and territories : intellectual enquiry and the cultures of disciplines. Milton Keynes [England] ; Philadelphia, PA, Open University Press.

Borgman, C. L. (1990). Scholarly communication and bibliometrics. Newbury Park, Sage Publications.

Borgman, C. L. and J. Furner (2002). "Scholarly communication and bibliometrics." Annual Review of Information Science and Technology **36**: 3-72.

Brooks, T. (1986). "Evidence of Complex Citer Motivations." Journal of the American Society for Information Science **37**(1): 34-36.

Budd, J. M., M. E. Sievert, et al. (1998). "Phenomena of retraction - Reasons for retraction and citations to the publications." Jama-Journal of the American Medical Association **280**(3): 296-297.

Burnham, J. C. (1990). "The evolution of editorial peer review." Jama **263**(10): 1323-9.

Campanario, J. (2003). Citation Analysis. International Encyclopaedia of Information and Library Science. J. Feather. London, Routledge.

Case, D. O. and G. M. Higgins (2000). "How can we investigate citation behavior? A study of reasons for citing literature in communication." Journal of the American Society for Information Science **51**(7): 635-645.

Cleveland (1983). Introduction to Indexing and Abstracting. Littleton, CO, Libraries Unlimited, INC.

Colaianni, L. A. (1992). "Retraction, comment, and errata policies of the US National Library of Medicine." Lancet **340**(8818): 536-7.

Cronin, B. (2000). "Semiotics and evaluative bibliometrics." Journal of Documentation **56**(4): 440-453.

Devore (2001). Statistics The Exploration and Analysis of Data, Duxbury/Thompson Learning.

Diodato, V. P. (1994). Dictionary of bibliometrics. New York, Haworth Press.

Egghe, L. and R. Rousseau (1990). Introduction to informetrics : quantitative methods in library, documentation, and information science. Amsterdam ; New York, Elsevier Science Publishers.

Garfield, E. (1964). Essays of an information scientist 1. Philadelphia, ISI Press.

Garfield, E. (1970). "Citation indexing for studying science." Nature **227**(5259): 669-71.

Garfield, E. (1983). Citation indexing, its theory and application in science, technology, and humanities. Philadelphia, ISI Press.

Garfield, E. (1998). "From citation indexes to informetrics: Is the tail now wagging the dog?" Libri **48**(2): 67-80.

Garfield, E. and A. Welljamsdorof (1990). "The Impact of Fraudulent Research on the Scientific Literature - the Breuning,Stephen,E. Case." Jama-Journal of the American Medical Association **263**(10): 1424-1426.

Garvey, W. D. (1979). Communication, the essence of science : facilitating information exchange among librarians, scientists, engineers, and students. Oxford ; New York, Pergamon Press.

Hood, W. W. and C. S. Wilson (2001). "The literature of bibliometrics, scientometrics, and informetrics." Scientometrics **52**(2): 291-314.

Kaplan, N. (1965). "The Norms of Citaiton Behavior: Prolegomena to the Footnote." American Documentation **16**(3): 179-184.

Kessler (1963). "Bibliographic Coupling Between Scientific Papers." American Documentation **14**(1): 10-25.

Kochan, C. A. and J. M. Budd (1992). "The Persistence of Fraud in the Literature - the Darsee Case." Journal of the American Society for Information Science **43**(7): 488-493.

Kotzin, S. and P. L. Schuyler (1989). "NLM's practices for handling errata and retractions." Bull Med Libr Assoc **77**(4): 337-42.

Kronick, D. A. (1976). A history of scientific & technical periodicals : the origins and development of the scientific and technical press, 1665-1790. Metuchen, N.J., Scarecrow Press.

Kronick, D. A. (1990). "Peer review in 18th-century scientific journalism." Jama **263**(10): 1321-2.

Leydesdorff, L. (1998). "Theories of Citation?" Scientometrics **43**(1): 5-25.

Lincoff, A. M. and E. J. Topol (1993). "Illusion of reperfusion. Does anyone achieve optimal reperfusion during acute myocardial infarction?" Circulation **88**(3): 1361-74.

Lindberg, D. A. (1987). "Retraction of research findings." Science **235**(4794): 1308.

MacRoberts (1996). "Problems of Citation Analysis." Scientometrics **36**(3): 435-444.

Marcus, E. (2005). "Retraction controversy." Cell **123**(2): 173-5.

McGrath, W. E. (1996). "The unit of analysis (objects of study) in bibliometrics and scientometrics." Scientometrics **35**(2): 257-264.

Mendel (1865). Experiments in Plant Hybridization. Natural History Society of Brunn, Brunn, Bohemia.

Merton, R. K. and N. W. Storer (1973). The sociology of science : theoretical and empirical investigations. Chicago, University of Chicago Press.

NLM "Coverage factsheet."

NLM "Errata Factsheet."

NLM "Functional Statement."

NLM "Mesh Factsheet."

NLM nlmhistory.html.

Pfeifer, M. P. and G. L. Snodgrass (1990). "The Continued Use of Retracted, Invalid Scientific Literature." Jama-Journal of the American Medical Association **263**(10): 1420-1423.

Popper, K. R. (1972). Objective knowledge; an evolutionary approach. Oxford,, Clarendon Press.

Poworoznek, E. L. (2003). "Linking of errata: Current practices in Online physical sciences journals." Journal of the American Society for Information Science and Technology **54**(12): 1153-1159.

Price, D. J. d. S. (1986). Little science, big science-- and beyond. New York, Columbia University Press.

Small, H. (2004). "On the shoulders of Robert Merton: Towards a normative theory of citation." Scientometrics **60**(1): 71-79.

Smith, L. (1981). "Citation Analysis." Library Trends(Summer): 83-106.

Tague-Sutcliffe (1992). "An introduction to informetrics." Information Processing and Management **28**(1): 1-3.

VanRaan, A. F. J. (1997). "Scientometrics: State-of-the-art." Scientometrics **38**(1): 205-218.

Virgo (1971). "The Review Article: Its Characteristics and Problems." Library Quarterly **41**(4): 275-291.

Walter, G. (2000). ""Rubber stamping" retracted papers." Bull Med Libr Assoc **88**(1): 85.

Warren, K. S. (1981). Coping with the biomedical literature : a primer for the scientist and the clinician. New York, N.Y., Praeger.

Watson, J. D. and F. H. Crick (1953). "Molecular structure of nucleic acids; a structure for deoxyribose nucleic acid." Nature **171**(4356): 737-8.

Weinberg, B. H. (1974). "Bibliographic Coupling: A Review." Information Storage and Retrieval **10**((5-6)): 189-196.

Weinberg, B. H. (1997). "The earliest Hebrew citation indexes." Journal of the American Society for Information Science **48**(4): 318-330.

White, H. D. and K. W. McCain (1989). "Bibliometrics." Annual Review of Information Science and Technology **24**: 119-186.

Whitely, W. P., D. Rennie, et al. (1994). "The scientific community's response to evidence of fraudulent publication. The Robert Slutsky case." Jama **272**(2): 170-3.

Wilson, C. S. (1999). "Informetrics." Annual Review of Information Science and Technology **34**: 107-247.

Wright (1991). A citation context analysis of retracted scientific articles. Library and Information Services. College Park, MD, University of Maryland**:** 483.

Ziman, J. M. (1968). Public knowledge: an essay concerning the social dimension of science. London,, Cambridge U.P.

Zunde (1971). "Predicitive Models of Scientific Progress." Information Storage & Retrieval **7**: 103-109.

Appendix A: Glossary

Corrected and Republished Article: A type of publication that consists of a pair of articles, the first of which contains flaws and is known in this study as the "original" article. The other half of the pair is a corrected version of the original article and is designated the "republication" or "republished version". The two members of the article pair are nearly identical, having the same title and first author.

Regarding corrected and republished articles, the NLM offers the following:

"Occasionally, a journal may correct or amplify a previously-published article by republishing the article in its entirety, often to rectify an editorial or printing error in the original article. NLM creates a new citation for the republished article and indexes it with the additional Publication Type of Corrected and Republished Article [PT]. Text information appears in the PubMed citations for the original and republished articles (see examples below), and a link is created between them. In the MEDLINE display in PubMed, the correction information appears in the RPI (Corrected and republished in) field and RPF (Corrected and republished from) field." (http://www.nlm.nih.gov/pubs/fact sheets/errata.html)

Biomedical Literature: Scholarly documents published in any of the life or health sciences. In terms of this study, the contents of the Medline database.

Medline: MEDLINE is the largest component of PubMed, the U.S. National Library of Medicine's database of biomedical citations and abstracts. It is searchable on the Web at no cost. MEDLINE indexes over 4,800 journals published in the United States and more than 70 other countries primarily from 1966 to the present. MEDLINE includes references to articles indexed with terms from NLM's controlled vocabulary, MeSH. Citations in MEDLINE are from journals selected for inclusion in the database.

Core Clinical Journals: A list of approximately 100 especially influential biomedical journals maintained by Medline. Formerly known as the Abridged Index Medicus, it was established to provide access to selected biomedical journal literature “of immediate interest to the practicing physician" when on-line services were not readily available.

Web of Science (WOS): A product of the Thompson-ISI corporation that makes available to users the citation database covering thousands of journals known as the Science Citation Index (SCI). A citation database allows a special kind of searching, cited reference searching. With it, users can search backward and forward in time and across disciplines to obtain all the information relevant to their inquiry. The Web of Science and the SCI are crucial tools in this study and their significance was discussed in chapter 2 and are briefly revisited in this chapter. Thompson ISI also produces the Journal Citation Report, a quantitative

measure of citation among journals, which allows users to calculate two other related performance metrics that are useful to informetricians:

Half-life & Obsolescence: Obsolescence is the name given to the phenomenon of diminishing citations to an article over time. The rate at which citation drops off over time is known as the article's half-life. The calculated average half-life for Medline indexed Core Clinical Journals is approximately 8 years. Thus, an article in that subset will have (statistically speaking), received half of its lifetime citations within eight years of publication and 75% of them within the first 16 years of publication.

Publication Lag: A delay (typically of one year), between the date of republication and the earliest sample in bibliometric studies of corrective literature. This delay is included to allow for the publication of articles that might have been in press at the time that the correction was published and so might legitimately have cited the repudiated document. The delay also allows a period of time for authors to read and assimilate the newer version of the document.

t-test: A statistical test that compares population or treatment means of paired samples.

P-value: The probability of obtaining another sample as divergent from what is predicted by the null hypothesis

significance level: The probability, assuming the null hypothesis, that the results would be observed and still be considered consistent with chance variation

	Overall Cites	Cited 1-4 YPR	Cited 5-8 YPR	Cited 9-12 YPR		Cocitation?			Medline link	WoS link				
n pairs	47	47	47	47										
Total Cites	1127	532	347	164		13		Total articles linked	80	30				
Sum Cites to Repub	597	265	195	108				Original Links to Repub	47	28				
Sum Cites to Orig	530	267	152	56				Repub Links to Orig	33	2				
Cites/Pair	23.978723	11.319149	7.3829787	3.4893617										
Cites/Rep	12.702128	5.6382979	4.1489362	2.2978723										
Cites/Orig	11.276596	5.6808511	3.2340426	1.1914894										
	Overall Cites	Cited 1-4 YPR	Cited 5-8 YPR	Cited 9-12 YPR										
% cites/yr to Repub	0.5297249	0.4981203	0.5619597	0.6585366										
% cites/yr to Orig	0.4702751	0.5018797	0.4380403	0.3414634										
Cit/Pair/yr	1.998227	2.8297872	1.8457447	0.8723404										
Cites/R/yr	1.0585106	1.4095745	1.037234	0.5744681										
Cites/O/yr	0.9397163	1.4202128	0.8085106	0.2978723										
Cites to both		13												
R Cites O?		21												

	Cited < 1YPR	Cited1-2 YPR	Cited 2-3 YPR	Cited 3-4 YPR	Cited 4-5 YPR	Cited 5-6 YPR	Cited 6-7 YPR	Cited 7-8 YPR	Cited 8-9 YPR	Cited 9-10 YPR	Cited 10-11 YPR	Cited 11-12 YPR	Cited 12+ YPR	Total Cites
n pairs	47	47	47	47	47	47	46	46	43	31	29	28	26	47
Total Cites	84	127	143	125	137	117	80	79	71	53	35	26	50	1127
Sum Cites to Repub	29	49	76	63	77	66	46	42	41	31	26	18	33	597
Sum Cites to Orig	55	78	67	62	60	51	34	37	30	22	9	8	17	530
Cites/Pair	1.787234	2.7021277	3.0425532	2.6595745	2.9148936	2.4893617	1.7391304	1.717391304	1.651162791	1.709677419	1.206896552	0.928571429	1.923076923	23.978723
% Cites/Rep	0.345238	0.3858268	0.5314685	0.504	0.5620438	0.5641026	0.575	0.53164557	0.577464789	0.58490566	0.742857143	0.692307692	0.66	0.5297249
% Cites/Orig	0.654762	0.6141732	0.4685315	0.496	0.4379562	0.4358974	0.425	0.46835443	0.422535211	0.41509434	0.257142857	0.307692308	0.34	0.4702751

Version	Author	Biblio Info	Title	Journal
Repub	Johnson BA	1999 Mar 15;59(6):1537-46	Flexible sigmoidoscopy: screening for colorectal cancer	Am Fam Physician
Original	Johnson BA	1999 Jan 15;59(2):313-24, 327-8	Flexible sigmoidoscopy: screening for colorectal cancer	Am Fam Physician
Repub	Bax T, Sheppard BC, Crass RA	1999 Feb 15;59(4):893-906	Surgical options in the management of groin hernias	Am Fam Physician
Original	Bax T, Sheppard BC, Crass RA.	1999 Jan 1;59(1):143-56.	Surgical options in the management of groin hernias.	Am Fam Physician
Repub	Macchi G, Jones EG	1997 Apr;86(4):670-85	Toward an agreement on terminology of nuclear and subnuclear d	JNeurosurg
Original	Macchi G, Jones EG.	1997 Jan;86(1):77-92.	Toward an agreement on terminology of nuclear and subnuclear d	JNeurosurg
Repub	Reynolds EM, Ryan DP, Doody DP	1993 Jun;21(6):944-7	Permissive hypercapnia and pressure-controlled ventilation as trea	Crit Care Med
Original	Reynolds EM, Ryan DP, Doody DP	1993 Mar;21(3):468-71	Permissive hypercapnia and pressure-controlled ventilation as trea	Crit Care Med
Repub	Truhan AP	1991 Dec;30(12):676-81	Sun protection in childhood	Clin Pediatr (Phila)
Original	Truhan AP	1991 Jul;30(7):412-21	Sun protection in childhood	Clin Pediatr (Phila)
Repub	Labrie C, Trudel C	1991 Jul;129(1):566-8	Combination of an antiandrogen and a 5 alpha-reductase inhibitor	Endocrinology
Original	Labrie C, Trudel C	1991 Mar;128(3):1673-5	Combination of an antiandrogen and a 5 alpha-reductase inhibitor	Endocrinology
Repub	Cantor KP, Booze CF Jr.	1991 Mar-Apr;46(2):110-6.	Mortality among aerial pesticide applicators and flight instructors: a	Arch Environ Health
Original	Cantor KP, Booze CF Jr.	1990 Sep-Oct;45(5):295-302	Mortality among aerial pesticide applicators and flight instructors: a	Arch Environ Health
Repub	Joseph AC.	1990 Nov;20(11):18-24	Ambulatory care. An objective assessment	J Nurs Adm
Original	Joseph AC.	1990 Feb;20(2):27-33	Ambulatory care. An objective assessment	J Nurs Adm
Repub	Naoumov NV, Portmann BC	1990 Oct;99(4):1248-53.	Detection of hepatitis B virus antigens in liver tissue. A relation to v	Gastroenterology.
Original	Naoumov NV, Portmann BC	1990 Sep;99(3):793-8	Detection of hepatitis B virus antigens in liver tissue. A relation to v	Gastroenterology.
Repub	Mountjoy KG, Flier JS.	1990 Oct;127(4):2025-34.	Vanadate regulates glucose transporter (Glut-1) expression in NIH	Endocrinology.
Original	Mountjoy KG, Flier JS.	1990 Jun;126(6):2778-87	Vanadate regulates glucose transporter (Glut-1) expression in NIH	Endocrinology.
Repub	Berlin RG.	1990 Jun;98(6):1732.	Famotidine is devoid of negative inotropic effect.	Gastroenterology.
Original	Berlin RG.	1990 Mar;98(3):805-6.	Famotidine is devoid of negative inotropic effect.	Gastroenterology.
Repub	Cheatham ML, Safcsak K	1998 May;186(5):594-5	Intraabdominal pressure: a revised method for measurement	J Am Coll Surg
Original	Cheatham ML, Safcsak K	1998 Mar;186(3):368-9	Intraabdominal pressure: a revised method for measurement	J Am Coll Surg
Repub	MacDonald AS, Maizels RM	1998 Apr 15;160(8):4124-32	Requirement for in vivo production of IL-4, but not IL-10, in the ind	J Immunol
Original	MacDonald AS, Maizels RM	1998 Feb 1;160(3):1304-12	Requirement for in vivo production of IL-4, but not IL-10, in the ind	J Immunol
Repub	Brodsky MC, Rettele GA	1998 Jan;116(1):107-9	Protracted postsurgical blindness with visual recovery following op	Arch Ophthalmol
Original	Brodsky MC, Rettele GA	1997 Nov;115(11):1473-4	Protracted postsurgical blindness with visual recovery following op	Arch Ophthalmol
Repub	Coller BS	1998 Jan 6-13;97(1):5-9	Monitoring platelet GP IIb/IIIa antagonist therapy	Circulation
Original	Coller BS	1997 Dec 2;96(11):3828-32	Monitoring platelet GP IIb/IIIa antagonist therapy	Circulation
Repub	van den Bergh AA, Rozario CJ	1996 Aug;51(8):804	Fentanyl-induced laryngospasm?	Anaesthesia
Original	van den Bergh AA, Rozario CJ	1996 Feb;51(2):206	Fentanyl-induced laryngospasm?	Anaesthesia

Author	<1yr	1-2 YPR	2-3 YPR	3-4 YPR	4-5 YPR	5-6 YPR	6-7 YPR	7-8 YPR	8-9 YPR	9-10 YPR	10-11 YPR	11-12 YPR	12+ YPR
Johnson BA	2	0	0	0	0	0	NA	NA	NA	NA	NA	NA	NA
Johnson BA	0	0	0	0	1	0	NA	NA	NA	NA	NA	NA	NA
Bax T, Sheppard BC, Crass RA	0	0	0	0	0	0	0	0	NA	NA	NA	NA	NA
Bax T, Sheppard BC, Crass RA.	1	0	0	0	1	0	0	0	NA	NA	NA	NA	NA
Macchi G, Jones EG	2	5	3	4	4	7	4	3	6	NA	NA	NA	NA
Macchi G, Jones EG.	3	1	2	2	1	1	1	0	2	NA	NA	NA	NA
Reynolds EM, Ryan DP, Doody DP	0	0	1	1	1	1	2	1	1	0	0	0	NA
Reynolds EM, Ryan DP, Doody DP	0	3	0	2	1	1	0	0	0	0	0	0	NA
Truhan AP	0	0	0	0	4	9	1	3	5	3	2	4	2
Truhan AP	0	0	1	0	2	1	0	2	0	0	0	0	0
Labrie C, Trudel C	1	4	5	1	1	1	0	1	0	0	0	0	1
Labrie C, Trudel C	3	2	0	1	0	2	2	0	1	0	0	0	0
Cantor KP, Booze CF Jr.	0	2	1	1	2	2	3	1	2	1	1	2	2
Cantor KP, Booze CF Jr.	1	1	1	0	0	0	0	2	0	0	0	0	0
Joseph AC.	0	0	0	0	2	0	1	0	0	0	0	0	0
Joseph AC.	0	0	0	0	0	0	1	0	0	0	0	0	0
Naoumov NV, Portmann BC	2	3	2	3	4	2	2	4	3	3	2	1	6
Naoumov NV, Portmann BC	0	3	2	0	0	1	0	0	0	0	0	0	0
Mountjoy KG, Flier JS.	1	2	3	1	3	3	3	0	2	1	1	0	0
Mountjoy KG, Flier JS.	2	4	2	3	1	4	0	1	0	0	2	0	0
Berlin RG.	0	0	0	0	0	0	0	0	0	0	0	0	0
Berlin RG.	0	0	0	0	0	1	0	0	0	0	0	0	0
Cheatham ML, Safcsak K	2	1	7	1	3	4	8	3	0	NA	NA	NA	NA
Cheatham ML, Safcsak K	1	1	1	1	1	0	0	1	1	NA	NA	NA	NA
MacDonald AS, Maizels RM	0	2	5	9	7	2	2	2	NA	NA	NA	NA	NA
MacDonald AS, Maizels RM	1	4	6	3	3	2	3	3	NA	NA	NA	NA	NA
Brodsky MC, Rettele GA	0	1	1	1	2	0	1	1	0	NA	NA	NA	NA
Brodsky MC, Rettele GA	2	0	0	2	0	0	1	0	0	NA	NA	NA	NA
Coller BS	8	8	8	11	4	2	4	2	0	NA	NA	NA	NA
Coller BS	2	7	5	3	3	4	0	0	0	NA	NA	NA	NA
van den Bergh AA, Rozario CJ	0	0	0	0	0	0	0	0	0	NA	NA	NA	NA
van den Bergh AA, Rozario CJ	1	0	0	0	0	0	0	0	0	NA	NA	NA	NA

Author	Sum(1-4)Y	Sum(5-9)Y	Sum(9-12)Y	Sum(1-12)Y	Overall cites	Cocitation?	R cites O?	Medline point	WoS point
Johnson BA	0	0	0	0	2	0		1	1
Johnson BA	1	0	0	1	1		0	1	0
Bax T, Sheppard BC, Crass RA	0	0	0	0	0	0		1	1
Bax T, Sheppard BC, Crass RA.	1	0	0	1	2		1	1	0
Macchi G, Jones EG	16	20	0	36	38	1		1	1
Macchi G, Jones EG.	6	4	0	10	13		1	1	0
Reynolds EM, Ryan DP, Doody DP	3	5	0	8	8	0		1	0
Reynolds EM, Ryan DP, Doody DP	6	1	0	7	7		0	NA	1
Truhan AP	4	18	11	33	33	0		1	0
Truhan AP	3	3	0	6	6		0	NA	0
Labrie C, Trudel C	11	2	1	14	15	0		1	0
Labrie C, Trudel C	3	5	0	8	11		0	NA	0
Cantor KP, Booze CF Jr.	6	8	6	20	20	0		1	0
Cantor KP, Booze CF Jr.	2	2	0	4	5		0	NA	0
Joseph AC.	2	1	0	3	3	0		1	0
Joseph AC.	0	1	0	1	1		0	NA	0
Naoumov NV, Portmann BC	12	11	12	35	37	0		1	0
Naoumov NV, Portmann BC	5	1	0	6	6		0	NA	0
Mountjoy KG, Flier JS.	9	8	2	19	20	0		1	0
Mountjoy KG, Flier JS.	10	5	2	17	19		0	NA	0
Berlin RG.	0	0	0	0	0	0		1	0
Berlin RG.	0	1	0	1	1		0	1	0
Cheatham ML, Safcsak K	12	15	0	27	29	0		1	1
Cheatham ML, Safcsak K	4	2	0	6	7		1	1	0
MacDonald AS, Maizels RM	23	6	0	29	29	3		1	1
MacDonald AS, Maizels RM	16	8	0	24	25		1	1	0
Brodsky MC, Rettele GA	5	2	0	7	7	0		1	1
Brodsky MC, Rettele GA	2	1	0	3	5		1	1	0
Coller BS	31	8	0	39	47	0		1	1
Coller BS	18	4	0	22	24		0	1	NA
van den Bergh AA, Rozario CJ	0	0	0	0	0	0		1	1
van den Bergh AA, Rozario CJ	0	0	0	0	1		1	1	0

Version	Author	Biblio Info	Title	Journal
Repub	Hannan EL, Stone CC	1997 Dec;134(6):1120-8	Public release of cardiac surgery outcomes data in New York: wha	Am Heart J
Original	Hannan EL, Stone CC	1997 Jul;134(1):55-61	Public release of cardiac surgery outcomes data in New York: wha	Am Heart J
Repub	Game CJ, Sanli H	1997 Oct;106(10 Pt 1):93-6	Waveforms of cochlear implant-evoked auditory brain stem respor	Ann Otol Rhinol Laryngol
Original	Game CJ, Sanli H	1995 Sep;166:93-6	Waveforms of cochlear implant-evoked auditory brain stem respor	Ann Otol Rhinol Laryngol
Repub	Weinberg WA, Harper CR	1997 Apr;130(4):665-9	Attention deficit hyperactivity disorder: a disease or a symptom co	J Pediatr
Original	Weinberg WA, Harper CR	1997 Jan;130(1):6-9.	Attention deficit hyperactivity disorder: a disease or a symptom co	J Pediatr
Repub	Lukinius A, Korsgren O	1997 Apr;138(4):5319-25	Expression of islet amyloid polypeptide in fetal and adult porcine a	Endocrinology
Original	Lukinius A, Korsgren O	1996 Dec;137(12):5319-25	Expression of islet amyloid polypeptide in fetal and adult porcine a	Endocrinology
Repub	Lee J, Nunn J, Wright C	1997 Jan;76(1):70-2	Height and weight achievement in cleft lip and palate	Arch Dis Child
Original	Lee J, Nunn J, Wright C	1996 Oct;75(4):327-9	Height and weight achievement in cleft lip and palate	Arch Dis Child
Repub	Guattery JM, Faloon WW	1997 Jan 1;126(1):88	Effect of ethinyl estradiol on chronic active hepatitis	Ann Intern Med
Original	Guattery JM, Faloon WW	1996 Oct 15;125(8):700	Effect of ethinyl estradiol on chronic active hepatitis	Ann Intern Med
Repub	Rosenberg E	1996 Sep;154(3 Pt 1):827-8	The 1995 update of recommendations for a standard technique fo	Am J Respir Crit Care Med
Original	Rosenberg E	1996 Jul;154(1):265-6	The 1995 update of recommendations for a standard technique fo	Am J Respir Crit Care Med
Repub	Miles MM, Shaw RJ	1996 May 11;312(7040):1205	Effect of inadvertent intradermal administration of high dose percu	BMJ
Original	Miles MM, Shaw RJ	1996 Apr 20;312(7037):1014	Effect of inadvertent intradermal administration of high dose percu	BMJ
Repub	Barach P, Rivkind A	1998 Aug;32(2):224-33	Emergency preparedness and response in Israel during the Gulf W	Ann Emerg Med. .
Original	Barach P, Rivkind A	1997 Oct;30(4):513-21	Emergency preparedness and response in Israel during the Gulf W	Ann Emerg Med. .
Repub	Hayes N, Shaw IH	1995 Mar;82(3):following 426	Comparison of conventional Lewis-Tanner two-stage oesophagec	Br J Surg
Original	Hayes N, Shaw IH	1995 Jan;82(1):95-7	Comparison of conventional Lewis-Tanner two-stage oesophagec	Br J Surg
Repub	Buckley N, Bates AS	1995 Feb;80(2):4 p following 692	p53 protein accumulates in Cushings adenomas and invasive non	J Clin Endocrinol Metab
Original	Buckley N, Bates AS	1994 Nov;79(5):1513-6	p53 Protein accumulates in Cushings adenomas and invasive non	J Clin Endocrinol Metab
Repub	McGowan CC, Cover TL	1994 Nov;107(5):1573-8	The proton pump inhibitor omeprazole inhibits acid survival of Heli	Gastroenterology
Original	McGowan CC, Cover TL	1994 Sep;107(3):738-43	The proton pump inhibitor omeprazole inhibits acid survival of Heli	Gastroenterology
Repub	Pohl LR, Martin JL	1994 Oct;37(10):1557	Immunochemical methods of studying the mechanism of diclofena	Arthritis Rheum
Original	Pohl LR, Martin JL	1994 Jul;37(7):1112	Immunochemical methods of studying the mechanism of diclofena	Arthritis Rheum
Repub	Hoey DE, Nicol M	1994 Oct;135(4):1553-60	Primary cultures of bovine inner zone adrenocortical cells secrete	Endocrinology
Original	Hoey DE, Nicol M	1994 Mar;134(3):1553-60	Primary cultures of bovine inner zone adrenocortical cells secrete	Endocrinology
Repub	Wu CW, Hsieh MJ	1994 Jun 15;73(12):3109-14	Lymph node metastasis from carcinoma of the distal one-third of t	Cancer
Original	Wu CW, Hsieh MJ	1994 Apr 15;73(8):2059-64	Lymph node metastasis from carcinoma of the distal one-third of t	Cancer
Repub	Wallbridge DR, MacIntyre HE	1994 Jun;71(6):597-9	Increase in plasma beta endorphins precedes vasodepressor synd	Br Heart J
Original	Wallbridge DR, MacIntyre HE	1994 May;71(5):446-8	Increase in plasma beta endorphins precedes vasodepressor synd	Br Heart J
Repub	Bulun SE, Rosenthal IM	1994 Feb;78(2):1616-21	Use of tissue-specific promoters in the regulation of aromatase cyt	J Clin Endocrinol Metab
Original	Bulun SE, Rosenthal IM	1993 Dec;77(6):1616-21	Use of tissue-specific promoters in the regulation of aromatase cyt	J Clin Endocrinol Metab

Author	<1yr	1-2 YPR	2-3 YPR	3-4 YPR	4-5 YPR	5-6 YPR	6-7 YPR	7-8 YPR	8-9 YPR	9-10 YPR	10-11 YPR	11-12 YPR	12+ YPR
Hannan EL, Stone CC	0	4	2	2	2	2	3	2	2	NA	NA	NA	NA
Hannan EL, Stone CC	3	2	3	5	2	5	2	2	1	NA	NA	NA	NA
Game CJ, Sanli H	0	0	1	0	1	0	0	0	0	NA	NA	NA	NA
Game CJ, Sanli H	0	0	1	0	1	0	0	0	0	NA	NA	NA	NA
Weinberg WA, Harper CR	1	0	3	0	2	2	1	2	1	NA	NA	NA	NA
Weinberg WA, Harper CR	1	0	1	1	0	1	0	1	0	NA	NA	NA	NA
Lukinius A, Korsgren O	0	0	0	1	0	0	0	1	0	NA	NA	NA	NA
Lukinius A, Korsgren O	2	1	1	1	2	0	1	2	0	NA	NA	NA	NA
Lee J, Nunn J, Wright C	1	1	3	0	1	1	0	1	1	NA	NA	NA	NA
Lee J, Nunn J, Wright C	1	0	0	2	0	0	0	0	0	NA	NA	NA	NA
Guattery JM, Faloon WW	0	0	0	1	1	0	0	0	0	NA	NA	NA	NA
Guattery JM, Faloon WW	0	1	0	0	1	0	0	0	0	NA	NA	NA	NA
Rosenberg E	0	0	1	0	0	0	1	0	0	0	NA	NA	NA
Rosenberg E	1	0	0	1	0	0	0	0	1	2	NA	NA	NA
Miles MM, Shaw RJ	0	0	0	1	1	1	1	0	0	0	NA	NA	NA
Miles MM, Shaw RJ	1	0	0	0	0	0	0	0	0	0	NA	NA	NA
Barach P, Rivkind A	0	0	1	1	2	0	2	1	NA	NA	NA	NA	NA
Barach P, Rivkind A	0	0	0	1	1	2	0	0	NA	NA	NA	NA	NA
Hayes N, Shaw IH	0	0	0	0	1	0	0	0	0	0	0	NA	NA
Hayes N, Shaw IH	2	1	2	0	0	0	0	1	0	0	0	NA	NA
Buckley N, Bates AS	0	1	2	2	2	0	1	0	1	1	0	0	NA
Buckley N, Bates AS	2	6	6	7	4	3	5	3	5	2	2	1	NA
McGowan CC, Cover TL	2	4	3	6	8	4	1	4	3	2	0	1	0
McGowan CC, Cover TL	6	14	6	4	5	4	4	1	1	0	2	0	0
Pohl LR, Martin JL	0	0	0	0	0	0	0	0	0	0	0	0	0
Pohl LR, Martin JL	1	0	0	0	0	0	0	0	0	0	0	0	0
Hoey DE, Nicol M	0	0	0	0	0	0	0	0	0	0	0	0	0
Hoey DE, Nicol M	0	0	0	2	1	2	0	1	2	1	0	1	0
Wu CW, Hsieh MJ	0	0	0	0	0	1	0	1	0	0	0	0	0
Wu CW, Hsieh MJ	0	3	6	2	2	2	0	0	1	1	1	0	0
Wallbridge DR, MacIntyre HE	0	1	3	3	2	1	0	0	1	2	0	0	0
Wallbridge DR, MacIntyre HE	1	3	2	2	4	2	0	2	0	0	0	0	0
Bulun SE, Rosenthal IM	0	1	0	0	1	1	0	1	2	0	5	1	0
Bulun SE, Rosenthal IM	3	4	7	6	8	3	3	9	5	5	0	0	2

Author	Sum(1-4)Y	Sum(5-9)Y	Sum(9-12)Y	Sum(1-12)Y	Overall cites	Cocitation?	R cites O?	Medline point	WoS point
Hannan EL, Stone CC	10	9	0	19	19	0		1	1
Hannan EL, Stone CC	12	10	0	22	25		1	1	0
Game CJ, Sanli H	2	0	0	2	2	1		1	1
Game CJ, Sanli H	2	0	0	2	2		0	1	0
Weinberg WA, Harper CR	5	6	0	11	12	0		1	1
Weinberg WA, Harper CR	2	2	0	4	5		1	1	0
Lukinius A, Korsgren O	1	1	0	2	2	0		1	1
Lukinius A, Korsgren O	5	3	0	8	10		1	1	0
Lee J, Nunn J, Wright C	5	3	0	8	9	0		1	1
Lee J, Nunn J, Wright C	2	0	0	2	3		1	1	0
Guattery JM, Faloon WW	2	0	0	2	2	0		1	0
Guattery JM, Faloon WW	2	0	0	2	2		0	1	0
Rosenberg E	1	1	0	2	2	1		1	1
Rosenberg E	1	1	2	4	5		1	1	0
Miles MM, Shaw RJ	2	2	0	4	4	0		1	1
Miles MM, Shaw RJ	0	0	0	0	1		1	1	0
Barach P, Rivkind A	4	3	0	7	7	0		1	1
Barach P, Rivkind A	2	2	0	4	4		0	1	0
Hayes N, Shaw IH	1	0	0	1	1	0		1	1
Hayes N, Shaw IH	3	1	0	4	6		1	1	0
Buckley N, Bates AS	7	2	1	10	10	3		1	1
Buckley N, Bates AS	23	16	5	44	46		1	1	0
McGowan CC, Cover TL	21	12	3	36	38	0		1	1
McGowan CC, Cover TL	29	10	2	41	47		1	1	0
Pohl LR, Martin JL	0	0	0	0	0	0		1	1
Pohl LR, Martin JL	0	0	0	0	1		1	1	0
Hoey DE, Nicol M	0	0	0	0	0	0		1	1
Hoey DE, Nicol M	3	5	2	10	10		0	1	0
Wu CW, Hsieh MJ	0	2	0	2	2	1		1	0
Wu CW, Hsieh MJ	13	3	2	18	18		0	1	0
Wallbridge DR, MacIntyre HE	9	2	2	13	13	0		1	1
Wallbridge DR, MacIntyre HE	11	4	0	15	16		1	1	0
Bulun SE, Rosenthal IM	2	4	6	12	12	1		1	1
Bulun SE, Rosenthal IM	25	20	7	52	55		1	1	0

Version	Author	Biblio Info	Title	Journal
Repub	Wase RE Jr, Cardwell P	1994 Jan;23(1):30	XAP--an alternative to cocaine for topical anesthesia	Ann Emerg Med
Original	Wase RE Jr, Cardwell P	1993 Nov;22(11):1776-7	XAP--an alternative to cocaine for topical anesthesia	Ann Emerg Med
Repub	Bonke B, Jelicic M	1993 Dec;48(12):1122	Information processing under anaesthesia	Anaesthesia
Original	**See 8305087 in Medline**	1993 Sep;48(9):820-1	Information processing under anaesthesia	Anaesthesia
Repub	Yentis SM, Jankowski S	1993 Jun;48(6):557-9	Intermittent thiopentone for teaching fibreoptic nasotracheal intuba	Anaesthesia
Original	Yentis SM, Jankowski S		Intermittent thiopentone for teaching fibreoptic nasotracheal intuba	Anaesthesia
Repub	Vercaeren I, Winderickx J	1993 Mar;132(3):2496-502	An effect of androgens on the length of the poly(A)-tail and alterna	Endocrinology
Original	Vercaeren I, Winderickx J	1992 Dec;131(6):2496-502	An effect of androgens on the length of the poly(A)-tail and alterna	Endocrinology
Repub	Slovis TL, Meza MP	1993 Jan;160(1):141-2	Aneurysm of a nonpatent ductus arteriosus in a neonate: CT findir	AJR Am J Roentgenol
Original	Slovis TL, Meza MP	1992 Oct;159(4):839-40	Aneurysm of a nonpatent ductus arteriosus in a neonate: CT findir	AJR Am J Roentgenol
Repub	Andrews MW, Amparo EG	1993 Jan;160(1):139-40	Wilms' tumor in a patient with Beckwith-Wiedemann syndrome: on	AJR Am J Roentgenol
Original	Andrews MW, Amparo EG	1992 Oct;159(4):835-6	Wilms' tumor in a patient with Beckwith-Wiedemann syndrome: on	AJR Am J Roentgenol
Repub	Veldhuis JD, Urban RJ	1992 Sep;75(3):707-13	Attenuation of luteinizing hormone secretory burst amplitude as a	J Clin Endocrinol Metab
Original	Veldhuis JD, Urban RJ	1992 Jul;75(1):52-8	Attenuation of luteinizing hormone secretory burst amplitude as a	J Clin Endocrinol Metab
Repub	Gandhi MR, Brown P	1992 Sep;65(777):838	The use of theophylline, an adenosine antagonist in the preventior	Br J Radiol
Original	Gandhi MR, Brown P	1992 May;65(773):459	The use of theophylline, an adenosine antagonist in the preventior	Br J Radiol
Repub	Cho NC, Han HJ	1992 Aug 15;114(2):235-6	Central retinal artery occlusion after varicella	Am J Ophthalmol
Original	Cho NC, Han HJ	1992 May 15;113(5):591-2	Central retinal artery occlusion after varicella	Am J Ophthalmol 1992
Repub	Shaw GM, Malcoe LH	1992 May-Jun;47(3):236-8	Residential mobility during pregnancy for mothers of infants with o	Arch Environ Health
Original	Shaw GM, Malcoe LH	1991 Sep-Oct;46(5):310-2	Residential mobility during pregnancy for mothers of infants with o	Arch Environ Health
Repub	Rao SP, Teitlebaum J	1992 May;146(5):539-40	Intravenous immune globulin and aseptic meningitis	Am J Dis Child
Original	Rao SP, Teitlebaum J	1992 Feb;196(2):147	Intravenous immune globulin and aseptic meningitis	Am J Dis Child
Repub	Hattersley AT, Lo YM	1992 Feb 22;339(8791):459-60	Failure to detect cytomegalovirus DNA in pancreas in type 2 diabe	Lancet
Original	Hattersley AT, Lo YM	1992 Feb 8;339(8789):335-6	Failure to detect cytomegalovirus DNA in pancreas in type 2 diabe	Lancet
Repub	Attardi B, Vaughan J, Vale W	1992 Jan;130(1):557-9	Regulation of FSH beta messenger ribonucleic acid levels in the ra	Endocrinology
Original	Attardi B, Vaughan J, Vale W	1991 Nov;129(5):2802-4	Regulation of FSH beta messenger ribonucleic acid levels in the ra	Endocrinology
Repub	Conneally PM	1991 Aug;48(8):757-9	Association between the D2 dopamine receptor gene and alcoholi	Arch Gen Psychiatry
Original	Conneally PM	1991 Jul;48(7):664-6	Association between the D2 dopamine receptor gene and alcoholi	Arch Gen Psychiatry

Author	<1yr	1-2 YPR	2-3 YPR	3-4 YPR	4-5 YPR	5-6 YPR	6-7 YPR	7-8 YPR	8-9 YPR	9-10 YPR	10-11 YPR	11-12 YPR	12+ YPR
Wase RE Jr, Cardwell P	0	0	0	0	0	0	0	0	0	0	0	0	0
Wase RE Jr, Cardwell P	0	0	1	0	2	0	0	0	1	0	0	0	0
Bonke B, Jelicic M	0	0	1	1	0	0	0	0	1	0	0	0	0
See 8305087 in Medline	1	0	1	0	0	0	0	0	0	0	0	0	0
Yentis SM, Jankowski S	1	0	0	0	0	0	0	0	0	1	0	0	0
Yentis SM, Jankowski S	0	1	0	0	0	1	0	0	0	0	0	0	0
Vercaeren I, Winderickx J	0	0	0	0	0	0	0	0	0	0	0	0	0
Vercaeren I, Winderickx J	1	3	2	3	3	1	1	1	0	1	0	0	0
Slovis TL, Meza MP	0	0	0	0	1	1	1	1	0	0	0	0	0
Slovis TL, Meza MP	1	0	0	0	0	0	0	0	0	0	0	1	1
Andrews MW, Amparo EG	0	1	3	2	1	2	1	0	2	1	1	2	0
Andrews MW, Amparo EG	0	0	0	0	0	0	1	0	0	0	0	0	0
Veldhuis JD, Urban RJ	3	3	9	6	8	4	1	3	4	6	6	2	6
Veldhuis JD, Urban RJ	4	5	1	3	3	5	5	4	5	7	2	4	12
Gandhi MR, Brown P	0	1	0	1	1	3	0	0	0	0	0	0	3
Gandhi MR, Brown P	0	0	0	0	0	0	0	0	0	0	0	0	0
Cho NC, Han HJ	0	0	1	0	1	2	0	0	0	0	1	0	0
Cho NC, Han HJ	0	1	1	1	0	0	0	0	0	0	0	0	0
Shaw GM, Malcoe LH	0	0	0	0	0	1	1	1	2	9	6	4	11
Shaw GM, Malcoe LH	1	1	2	1	0	1	1	0	3	0	0	1	2
Rao SP, Teitlebaum J	1	0	3	2	1	1	1	3	0	0	1	0	0
Rao SP, Teitlebaum J	1	1	0	1	0	0	0	0	0	0	0	0	0
Hattersley AT, Lo YM	1	0	1	0	0	1	0	0	0	0	0	0	2
Hattersley AT, Lo YM	0	0	0	0	1	0	0	0	0	0	0	0	0
Attardi B, Vaughan J, Vale W	1	0	0	0	3	1	0	0	1	0	0	1	0
Attardi B, Vaughan J, Vale W	1	3	0	0	3	0	1	0	1	2	0	0	0
Conneally PM	0	4	3	1	0	4	0	0	1	1	0	0	0
Conneally PM	4	2	4	2	3	2	2	1	0	1	0	0	0

Author	Sum(1-4)Y	Sum(5-9)Y	Sum(9-12)Y	Sum(1-12)Y	Overall cites	Cocitation?	R cites O?	Medline point	WoS point
Wase RE Jr, Cardwell P	0	0	0	0	0	0		1	0
Wase RE Jr, Cardwell P	3	1	0	4	4		0	1	0
Bonke B, Jelicic M	2	1	0	3	3	0		1	1
See 8305087 in Medline	1	0	0	1	2		1	1	0
Yentis SM, Jankowski S	0	0	1	1	2	0		1	1
Yentis SM, Jankowski S	1	1	0	2	2		1	1	0
Vercaeren I, Winderickx J	0	0	0	0	0	0		1	1
Vercaeren I, Winderickx J	11	3	1	15	16		1	1	0
Slovis TL, Meza MP	1	3	0	4	4	0		1	1
Slovis TL, Meza MP	0	0	2	2	3		0	1	0
Andrews MW, Amparo EG	7	5	4	16	16	0		1	1
Andrews MW, Amparo EG	0	1	0	1	1		0	1	0
Veldhuis JD, Urban RJ	26	12	20	58	61	1		1	0
Veldhuis JD, Urban RJ	12	19	25	56	60		0	0	0
Gandhi MR, Brown P	3	3	3	9	9	0		1	0
Gandhi MR, Brown P	0	0	0	0	0		0	0	0
Cho NC, Han HJ	2	2	1	5	5	0		1	0
Cho NC, Han HJ	3	0	0	3	3		0	0	0
Shaw GM, Malcoe LH	0	5	30	35	35	0		1	0
Shaw GM, Malcoe LH	4	5	3	12	13		0	0	0
Rao SP, Teitlebaum J	6	5	1	12	13	0		1	0
Rao SP, Teitlebaum J	2	0	0	2	3		0	0	0
Hattersley AT, Lo YM	1	1	2	4	5	0		1	0
Hattersley AT, Lo YM	1	0	0	1	1		0	0	0
Attardi B, Vaughan J, Vale W	3	2	1	6	7	0		1	0
Attardi B, Vaughan J, Vale W	6	2	2	10	11		0	0	0
Conneally PM	8	5	1	14	14	1		1	0
Conneally PM	11	5	1	17	21		0	0	0

VITA

Gabriel Peterson was born in Wyoming in 1973, where he lived until his family moved to Albuquerque, New Mexico in 1987. He attended high school in Albuquerque and enrolled in New Mexico State University in 1990. In 1995, he graduated from NMSU with a B.S. in Biochemistry, a B.A. in Chemistry and a B.A. in Spanish. Following a year of work as an analytical chemist, Gabriel began graduate studies at the University of Texas at San Antonio, where in 1999 earned his M.S. in Biotechnology. Research in virology led to acquisition of skills as a molecular biologist including proficiency in the areas of cell culture, fermentation science and electron microscopy. Following a year of work as a molecular biologist, he was accepted into a program of doctoral study in the University of Missouri-Columbia School of Information Science and Learning Technologies. He is a recipient of a National Library of Medicine Bio- and Health- Informatics Research Training fellowship which was administered through the University of Missouri-Columbia Department of Health Management Informatics (School of Medicine).