SOME CHARACTERISTICS OF THE STRUCTURE OF THE LITERATURE OF BIOMEDICAL SCIENCE

By

Daniel Newton Obaka

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Stephen P. Harter
Director of Dissertation

Doctoral Committee: Stephen P. Harter, Chairman

Lester A. Nyhan

Ann J. Carmichael

Mary Murphy

Bernard M. Fry

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B. SCI JOURNAL CITATION REPORTS
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CHAPTER ONE

INTRODUCTION

Background Information

Scientific knowledge is generally viewed as objective knowledge, generated by the scientific method of inquiry and experimentally validated. Every new addition to the body of objective knowledge is an extension of the existing body of knowledge as recorded in scientific literature. In his Phenomenology and Models of Growth of Science, Moravcsik[1] noted an earlier observation by Derek Price that science is a body of knowledge growing at its epidermis, that is, along the research fronts based on knowledge acquired in most recent research.

But each incremental advancement in some way adds to, modifies, refines, or sometimes totally refutes the prior knowledge on which the advancement was based. Kuhn[2] described the additive process as "normal science," "research firmly based upon one or more past scientific achievements, achievements that some particular scientific community acknowledges as supplying the foundation for its further practice." In addition, he argued that the whole scientific enterprise is punctuated by revolutionary scientific discoveries of natural laws and theories. Thus, Einstein's general theory of relativity brought a revolutionary extension and generalization

of Newton's classical mechanics; and the heliocentric theory of Copernicus rejected and replaced Ptolemy's geocentric theory. These characteristics of the growth of science are shared by the literature generated by it. It can also be noted in addition that, apart from the normal goals of scientific research, sciences operate within an institutional structure.

An important by-product of the seventeenth century scientific revolution was the birth and growth of scientific specialties. This has resulted in greater specialization and finer differentiation of subject matter in scientific research. Thus, modern science is frequently described as a mosaic of scientific specialties. Small and Griffith succinctly brought this idea into focus:

> That science is a mosaic of specialties, and not a unified whole, either socially or intellectually is a frequently made assumption, but only recently has this infrastructure of science become the subject of systematic study. Most scientists have intuitive notions about the subdivisions of their fields, but no observer, however broadly trained, can gain an overall perspective on the scientific mosaic.[3]

Although difficult to prove, technology has been assumed to "grow out" of science or "give birth to" scientific interests or a dialectical interaction with it.[4] While the motives of basic science can be identified by its search for laws and natural constants of the broadest possible scope, those of technology attempt to apply the knowledge generated

by science to the solution of human problems. Thus, structurally, technology deals with less general characteristics of nature than does basic science. The nature of the interaction of the two distinct but related bodies of human knowledge is a logical consequence of their overlapping goals and identical empirical methodologies. In terms of identifying distinct boundaries between basic science and technology, Brooks[5] held that there exists a continuum of research activities varying from basic science to technology along which most research activities and orientations can be located.

Most scientists cherish this belief, that science through basic science research plays an important role in technological developments. They contend that after all, technology is "applied basic science research." In recent years, this assumption became the subject of intense study. In Project Hindsight,[6] an effort on the part of the U.S. Department of Defense, it was revealed that basic science research did not contribute much to the development of weapon systems. The study concluded that twenty of the most important military weapons came as a result of applied science research. However, a report with the Acronym TRACES,[7] prepared by Illinois Institute of Technology Research Institute for the National Science Foundation, revealed that by studying a longer time period than Project Hindsight, seventy percent of the basic science research studied, led to advances in magnetic ferrites, video tape records, the oral contraceptive pill, the electron microscope and matrix isolation. Battelle Laboratories[8]

came to the same conclusion that basic science research leads to significant advances in technological developments. Many agree that it is vital to pursue basic research not only because it increases knowledge of natural phenomena, but also because unexpected benefits often spring from it. This led to Mosteller's comment on general attitude to basic science research: "The go-no-go approach to basic science research seems to be a not very useful concept." He emphasized that "we need basic science research for new developments."[9]

Interaction Between Basic Biomedical Science and Clinical Medicine

The notion that technological advances largely depend on the basic science research can be extended to the study of biomedical science body of knowledge. Biomedical science forms a unique subdivision within the universe of scientific and technological body of knowledge. It is made up of two different but interrelated structures, the basic science and technology of biomedical science. Thus, biomedical science can be viewed as a "special universe" of knowledge of its own. These two interrelated structures of biomedical science can be viewed as an interplay of three professional activities in both basic scientific and technological research, education, and services. This interplay of activities is embedded in the two different but interrelated structural fields - basic biomedical science and clinical medicine. The two

fields have contributed to the phenomenal growth in both the knowledge and literature of biomedical science during the past three centuries.

Basic biomedical science and clinical medicine can be defined and distinguished on the basis of their primary objectives. Basic biomedical science has as its objective the generation of laws and natural constants relating to biomedical phenomena. In contrast, clinical medicine (the biomedical science equivalent to applied scientific research, technological research, and applied technology) is primarily concerned with direct or indirect application of the body of knowledge generated by basic biomedical science to the practice of medicine. In the course of its performance, clinical medicine may lead to the generation of new understanding of basic biomedical science phenomena. Under such circumstances, clinical medicine can be distinguished from basic biomedical science by the fact that the problems under investigation within clinical medicine research are mostly mission-oriented. In this context, clinical research works and its practice are planned on and directed to the application of the existing body of knowledge - basic biomedical science research results.

The continuing growth in both the knowledge and literature of biomedical science and its effective utilization, have become matters of significant concern to contemporary society, especially to biomedical scientists and other persons engaged in the production, collection, storage, retrieval and utilization of information. With regard to

their growths, basic biomedical science and clinical medicine are its two contributors.

The nature of the relationship between basic biomedical science and clinical medicine as primary factors in the advancement of medicine has been a subject of intense debate and investigation since the turn of this century. Over a century ago, Claude Bernard[10] called for an integration of experimental research with the study and practice of medicine: "if medicine is to be sure of itself, it must have physiology as its necessary base." Modern medicine views clinical medicine as a discipline that has its roots in the basic biomedical science.

Seeing the Johns Hopkins Medical School as an ideal, the Flexner Report published in 1910,[11] advocated basic science and clinical medicine in medical training. It called for emphasis on biological research: "Science," was to be the nucleus of medical education. Anatomy, biology, physiology, biochemistry and pharmacology are seen as laying the foundation of the later work of the clinical just as the physics furnishes a firm theoretical basis for the engineer. Today the teaching of the basic biomedical science subjects to medical students is fundamental in almost all medical schools throughout the world. Thus, basic biomedical science can be conceived as the bed-rock of clinical medicine.

An unclear and unscientific method of defending science research led Comroe and Dripps[12] to study and find a more objective justification for supporting basic biomedical

science research. They sought to evaluate how much basic biomedical science research really contributes to biomedical science, and to identify the "essential body of knowledge" required for each advancement. Asking over 100 specialists (biomedical scientists and clinical practitioners) to vote on the top ten advances in cardiovascular pulmonary medicine and surgery that occurred between 1945 and 1975 they discovered that out of 4000 articles, 2500 were perceived important to the discipline. They further identified and named 529 "key articles." The study concluded that 61.7% of the key research articles reported basic research and only 21.2% of the key articles were from clinical research. Their study thus gives a strong evidence of the dependence of major developments and research in clinical medicine upon basic biomedical science research.

In his article, Retrospectroscope: Insights Into Medical Discovery, Comroe further showed the dependence of biomedical science innovations and clinical medicine on basic biomedical science research when he observed:

> As you will see, everywhere that I have turned the Retrospectroscope, it has shown that scientists depend on the work of scientists who depend on the work of still others. Turned in some directions, especially outside of medical laboratories, it has revealed crucial discoveries essential to later medical miracles, were often made by those not directly concerned with diagnosing or curing or preventing disease, and that the work of many of these was judged to be impractical, impossible, irrelevant or absurd at the time of discovery.[13]

General Statement of the Problem

Our understanding of the manner in which the basic biomedical science and clinical medicine interact is still limited. While few will doubt that basic biomedical science research has been highly productive in recent years and that this has given solid foundation to advancement of medicine, the nature of this relationship is still not fully understood.

Viewing the areas of basic biomedical science and clinical medicine as consisting of a total system of biomedical science, the system undoubtedly possesses a set of complex interrelated objectives. These include: (1) the generation of the body of knowledge primarily related to the advancement of medicine, (2) the innovation concerned with synthesis and integration of previously existing body of knowledge into a demonstrated operational capability (medical developments), (3) the communication system needed for the transfer of the body of knowledge, and (4) the ability to maintain the continuing support for the growth and advancement of this knowledge.

The general problem then, which provides the context for this study, relates to the interrelated objectives of basic biomedical science and clinical medicine. The need for understanding these interrelationships has been motivated by the events of recent years where many seem to advocate the support of clinical medicine to the detriment of basic biomedical science. Of this trend, Shannon warns:

> . . . it must not be forgotten that medicine is a science based profession and separation of physician education from life science base would directly contribute to the development of mediocre physicians with a high rate of obsolescence.[14]

Previous studies seem to suggest that the development and growth of clinical medicine is closely related to basic biomedical science; that basic biomedical science provides "core research information" within the universe of biomedical science.[15] Within this context, it can be hypothesized that there is a direct relationship between the quality and quantity of literature generated by clinical medicine and the quality and quantity of literature of basic biomedical science. That is, one would expect there to be a definite interaction between the literature of basic biomedical science and the literature of clinical medicine in terms of the flow of research information. The general questions addressed in the study elaborate upon this idea.

Can the "effective direction"* of research information be shown to be from the basic biomedical science research orientation towards the clinical medicine research orientations? How does the increase of research literature affect this flow?

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*"Effective direction" of research information in the context of this study refers to an overall difference between the flow of number of citations from the basic biomedical science research orientation to other biomedical science research orientations and from the other biomedical science research orientations to the basic biomedical science research orientations.

Since published research literature is an empirical by-product of the activity of science, it is assumed in this study that biomedical science can be viewed through its literature - the literature of basic biomedical science research and that of clinical medicine. In scientific and professional tradition, scientists, researchers and practitioners refer to previous research. The literature is the prime means by which most of the biomedical scientists and clinicians keep up to date in the biomedical science field. Houghton beautifully illustrates this characteristic when he wrote:

> Papers beget papers; a scientist will read and assimilate the works of his precursors and peers and use their experience as a catalyst and stimulant to his own activity. Their papers will act as a platform and a spring-board for his published work and they will be cited in his papers. His own works will subsequently be cited by peers and heirs and so the fabric of the literature will be worked.[16]

Thus, there is a continuous research information exchange within and across the various research orientations within the universe of scientific knowledge. In the case of the universe of biomedical science, therefore, there ought to be an identifiable information exchange in the form of citations between the basic biomedical science research orientations and those of clinical medicine as clinical scientists refer to research information in basic biomedical science and basic biomedical scientists refer to research information in clinical medicine.

The general problem arising from the two-way (bi-directional flow of research information) is to determine whether the nature of the flow of research information is more from basic biomedical science research orientation than from clinical medicine. To examine this problem, this study considers the universe of biomedical science as made up of basic biomedical science, applied biomedical science, clinical, and clinical practice research orientations. These are designated as research shells to distinguish it from research levels classification of Narin.

Summary

This introductory chapter has provided a brief overview of the structure of science and its relationship with technology as reflected in the literature generated and utilized by both scientific and technological bodies of knowledge. The concept of science giving rise to technological developments was extended to the study of biomedical science.

Chapter two will review the related literature of research done in the area of classification of scientific knowledge. The work of Narin and others[17] as it relates to the concept of research level classification will be given special attention because this notion aided in arriving at the research shell of the present study.

The literature of citation studies concerning the structure of science and technology will also be reviewed. Studies reflecting the structure of biomedical science will

be given special attention. The flow of research information borders on the pattern of communication between various biomedical science specialties, and thus, studies conducted in this area are thoroughly reviewed.

Chapter three states the specific purposes of the study and the question of the pattern of flow of research information. It identifies the specific problems investigated and the hypotheses related to the study of these problems. The limitations of the study are also given.

Chapter four discusses the methodological procedures used to carry on the collection of the data, the analysis of the data and the interpretation of the results of the study.

Chapter five gives a detailed analysis and interpretation of the results of the study.

And finally, chapter six gives a brief comment on the implications of the findings in the study. It gives an overall summary of the study with suggestions for application of the study and for further study.

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CHAPTER TWO

REVIEW OF RELATED RESEARCH

Studies of Scientific Literature

Quantitative study of scientific literature is comparatively new and may be divided into four general but closely related areas.

The first includes the study of publications of subject productivity for the purpose of identifying the structure of growth of the literature generated by the given subject field. This kind of study is made by counting the papers, books, and other forms of writing in the subject area.

The second includes the study of the pattern of literature used in a given field for the purpose of identifying the particular subject literature that researchers cite most in the course of research works. This kind of study is often made by counting references cited.

The third includes the study of the structure of literature of a subject field for the purpose of identifying the interrelation between the different subject literatures and the pattern of flow of literature from one subject field to another. This kind of study is often made by examining cross-references between the literatures of the subject fields. This leads to the identification of the nature of interaction of one subject field on another and the subsequent networks of literature of the related subject fields.

Finally, the fourth type includes the study of the pattern of communication among scientists of various subject fields. This kind of study is often made by examining the various communication channels as they involve literature generated and used by the subject fields through the citation pattern. The study leads to the identification of the place of literature in the dissemination of information.

Publication or Productivity of Subject Field

The earliest study of the publication or productivity of literature in one of the biomedical science fields was made by Cole and Eales[1] in 1917 when they made statistical analysis of 5,436 writings of anatomy of animals published between 1543 and 1860. In this analysis, they discussed the fluctuation (with time) of the number of publications, the shift of publication from country to country, and correspondence between patterns on anatomy publications and external economic and political events. Cole and Eales in their study, for the first time, recognize the promise of publication analysis:

> . . . it seemed possible to reduce to geometrical form the activities of the corporate body of anatomical research and the relative importance from time to time of each country and division of the subject.[2]

In evaluating medical periodicals in 1936, Gregory[3] made a similar analysis of the literature of medical science and

commented upon frequency of citation, nationality and language for various journal literature in the field of medical science. This was followed by the study of Henkle.[4] In his study of literature productivity using the subject fields of biochemistry he found that current literature provides the most relevant and valuable source of information. From this period on, individual studies have been made of the literature in specialized subject fields such as pediatrics,[5] dentistry,[6] physiology[7] and schistosomiasis.[8] The last, by Warren and Goffman, concluded that the paper/author ratio remains constant with time. They were the first to offer recommendations to reduce the exposure to the entire literature and to increase the exposure to the literature of quality. They further suggested that no action should be taken to destroy the ecological balance between worthy literature and the total amount of biomedical science literature.

In their study of 1966, Bayer and Folger[9] made a correlational study between citations and productivity in science by comparing the citations received by 467 scientists earning their doctorate in biochemistry in 1957 and 1958. The citations came from the twenty-seven biochemistry journals covered by the Science Citation Index in 1967. The study shows that three times as many graduates of high quality than low quality institutions produced papers which were cited more than fifteen times. They also show that twice as many graduates of the lower quality departments had no citations.

In her 1974 doctoral dissertation at the University of Chicago, Virgo[10] studied citation rates and judges' ratings of papers in the medical literature. She used as judges a group of nine medical researchers who were actively engaged in the practice of clinical medicine and in research in surgery and radiology. The study shows that there is a high correlation between the judges' ratings of papers and the rate of citation.

Most of the studies employing the method of counting of papers, books and other forms of writings have been made for the purpose of indicating and demonstrating a relationship between the quantity and quality of research produced and the conditions under which they are produced. Another purpose was to discover the characteristics of the periodical literature in the subject fields and to draw general conclusions about the dispersion of the literature used in scientific research.

Use of Literature by Researchers

The pattern of the literature used by researchers in a subject field has been pioneered by the study made in 1927 by P. L. K. Gross and M. E. Gross.[11] In this study, the authors were searching for objective means of selecting those journals most likely to be of value in chemical research. This method, called "reference counting," or some modification of it has been used in research in various subject fields. As this study was extended to include other fields

of knowledge, the method used by Gross and Gross was refined and elaborated. The first writers to extend the method used by Gross and Gross to the study of literature of biomedical science were Brodman,[12] Sen Gupta[13] and Brennen.[14] Their various studies used the techniques of ranking periodicals from frequency of citation to aid in the selection of journals in the fields of biomedical science for medical libraries. Voigt[15] introduced an additional but significant characteristic of the literature of subject field. This characteristic was the "subject dispersion" of a field - the degree to which a research worker in a given subject field makes reference to the writing of other closely related subject fields.

In 1976, Narin and others, in extensive study of the structure of literature of biomedical science, extended these subject dispersion characteristics and introduced the concept of "influence measures" of subject fields. Three related influence measures were developed, each of which measured one aspect of a journal's influence with explicit recognition of the size factor. These measures included:

> The influence weight of the journal: a size-independent measure of the weighted number of citations a journal receives from other journals, normalized by the number of references the journal gives to other journals.
>
> The influence per publication for the journals: the weighted number of citations each article, note or review in a journal receives from other journals.
>
> The total influence of the journal: the influence per publication times the total number of publications.[16]

Thus, the concept of influence measures is derived from an analysis of referencing interactions among members of the set of literature of biomedical science being considered. Since this study, other related studies have been carried out. Pioneering studies by Garfield[17] and Price[18] have established patterns of development within particular fields. Garfield conceptualized the citation relationships as direct lines connecting later documents with earlier ones. The totality of such relationships constitutes an "historical map." This concept has led to a fruitful study at the Institute for Scientific Information providing the Atlas of Science."[19]

Most of the studies employing the reference-counting method or some other modified form of this have been made for the purpose of indicating the most frequently used journals in a specific field and the journals which are of most importance in the library. Recent studies, however, in this field have resulted in finding the sociological implications of the structure of literature and the pattern of its usage among various subject fields. One central issue for the use of literature from one research field by another that has not been directly addressed, and to be examined in this study, is the degree of interaction of one research literature with others.

Structure of Literature

The study of the structure of literature of any subject field was heralded by the study of Cason and Lubotsky.[20] The authors made a number of advances in using scientific journals to study the functioning of scientific community. This paper which was published in 1936, discussed the influence and dependence of psychological journals. It was mentioned that journal to journal citation analysis could be used to secure quantitative measures of the extent to which one psychological field influences and is influenced by each of the other psychological fields. This is the earliest study to address itself to the study of "subject literature relationship."

This was followed by studies of the citation links between papers. These new citation studies are providing different views of science. In his work on the sociology of science, Price[21] has shown that the distribution of references by age of cited papers provides a way of distinguishing between hard science, soft science and the humanities - each of which is built on a different social system and progress in a different manner and at a different rate.

A 1973 study by Small[22] examined co-citation as a measure of the association between pairs of frequently cited documents. The strengths of co-citation is defined as the number of times that two documents have been cited together; it provides a natural and quantitative way to group or cluster the cited documents. Co-citation identifies relationships between

papers which are regarded as important by authors in the specialty. The strength of co-citation between two papers can readily be determined from a citation index. This method has led to the possibility of clustering of documents which is useful in understanding the pattern of information dynamics within subject fields. From this type of study, Small[23] was able to show that the literature of biomedical science presents a structure that is quite different from the physical sciences.

As might be expected, citation analysis has always played a fundamental and productive role in the attempt to define the structure of science. Many studies, using the citation patterns between journals, have been able to define the disciplinary structure of science.[24] Goffman,[25] Jahn,[26] and Small[27] have all shown that a specialty is defined by a few critically important papers that appear early in its history. Small and Griffith[28, 29] in their studies have gone so far as to produce a map that showed all the high activity specialties in the natural sciences. Small, on his own, has extended this work to produce a map that shows the evolution of a single, biomedical science specialty, collagen research.[30] This same technique has led to the recent construction of Atlas of Science and the subsequent production of ISI Biomedical Science Index at the Institute for Scientific Information.[31]

The pioneering co-citation study by Small and Griffith[32] was designed to test two hypotheses. One was that science

is made up of a structure of specialties that can be defined by objective means. The other was that a particular citation measure of the common intellectual interest between two documents was a practical way of defining the structure. The technique used was co-citation strength, which is defined as the number of documents that have cited a given pair of documents. Co-citation therefore can be seen as a creative reversal of Kessler's bibliographic coupling concept,[33] which uses the number of references a given pair of documents have in common to measure the similarity of their subject matter. The weakness of bibliographic coupling technique in the study of structure of science is that the structure presumably is dynamic over time, whereas bibliographic coupling is a fixed measure. In contrast, co-citation strength reflects the frequency of being cited, which is a characteristic that is variable over time. The rationale behind the use of co-citation strength, therefore, lies in its reflection of shifts in research focus and relationships.

This classic methodology of Small has opened ways to the study of the structure of science and in particular, the study of the structure of biomedical science. The study leads to the understanding of the structure of biomedical science and also aids in the identification of the pattern of information flow among the biomedical scientists.

Most of the recent studies using the cross-citation technique have grown in importance because the need to understand the complex pattern of activities and communication

within the scientific community is highly related to the nature of the flow of literature of one subject to another. In the biomedical science field where the factors contributing to the generation and utilization of its literature depend on research activities, education, and services, such understanding of communication within its community is vitally important.

Some other studies provide evidence that specialties are the basic intellectual and social unit of the scientific mosaic. Crawford[34] described how specialty of sleep research is built around the communication between a small group of key individuals and research centers. Griffith and Mullins[35] have shown that small coherent groups are capable of producing major changes within disciplines. Crane's work of specialties in rural sociology and mathematics[36] has led her to the ideas of specialties forming a structure that can be mapped. Based on the conceptual foundations of the literary model of science that was validated by the D.N.A. history study, Price has used citation patterns to explore the structure of physics[37] and of its specialties.

While several studies have been done in the field of the structure of the literature of science, relatively little research has been directed toward the study of the nature of interaction between the literature of basic sciences and applied sciences. The studies in the field of biomedical science literature have been based generally on the identification of activities within each of the specialties without addressing the issue of the direction of flow of

research information within and across biomedical science research categories. And while efforts have been made to classify biomedical science into various structures of specialty and research levels using patterns of citations and the co-citation conept,[38] there has been no study directed toward finding the direction of the flow of research information. It is intended in this study, by classifying the universe of biomedical science into definable research orientations and by using citation analysis, to identify the direction of flow of research information within biomedical science.

Pattern of Communication Flow Among Scientists

The "communication problems" of scientists are often equated with "literature problems" in that the primary source of difficulty is assumed explicitly or implicitly to be changes in the characteristics of the scientific literature - its volume, growth, form, content or quality. In the discussion of these problems, phrases connoting an acute threat, such as "the publication explosion"[39, 40] or the "paper flood"[41] are commonly employed and assertions that scientific publication is deteriorating are frequent.

The communication problems of biomedical scientists in their tripartite functions are complex. In 1965, Sir Theodore Fox, former long-term editor of Lancet, pointed to a crisis in communication.[42] He suggested that medical

journals had outlived their usefulness, in large part because of editorial deficiencies and a lack of organization. He went further to say that we were approaching a period when the conventional journal would have to be replaced by more efficient, timely, and less-costly mechanism for the dissemination of information.

The crisis in biomedical science research communication has become one of the fundamental concerns of users and processors of biomedical science research information. Orr and Leeds[43] aptly described some of the concerns to include language, literature scatter, and volume, roughly in ascending order of expressed concern. Their study noted the rapid increase in the number of other languages other than English language as shown from the data of biochemistry literature. The study noted the implications of this trend for biomedical research communities as:

(a) foreign language will become progressively less satisfactory as it becomes more difficult to decide which languages to study; and

(b) individual biomedical scientists will become more dependent on translations. For abstracting-indexing services, the problems posed by the proliferation of scientific languages will be particularly difficult.

The scatter characteristic of the output of biomedical research has very important implications for any library or other information service that attempts to meet the needs

of broad segments of the biomedical science research community. These inherent problems in the characteristics of the literature of biomedical science have contributed to the nature of complexity in the pattern of communication flow among the biomedical scientists.

Measures of the growth of the literature of biomedical science show an exponential trend. While growth may stabilize in the future, as Price has suggested for the scientific literature,[44] it is important to note that the duty of differentiating and identifying quality literature from the universe of the scientific literature grows continually more difficult for both the scientists and information specialists. Scientists, information specialists and librarians must be more aware of how scientists communicate with each other. As long as science continues to grow, all of the communication activities must also increase. What is observed is the crystalization of old specialty areas and the growth of new specialties having high potentials of generating literature.

Admittedly, the steadily expanding volume of scientific information makes it increasingly difficult for the scientist to locate the information that he needs for his research. Hence, the need to evaluate problems in the context of the structure of scientific knowledge. Science in general and biomedical science in particular, utilize information both from within his own research subfield and from many other related subject fields as well. This makes it unlikely for scientist to have access to all the information that is

potentially useful in the format needed by him. The problems that he faces in obtaining the information he needs vary depending upon whether he is seeking the information within his own research area or whether he needs information from another subject field. In general, he is likely to have more difficulties when he seeks information out of his subject area than he does when he seeks it within his own subject field.

Some "socio-scientific" communication problems exist where scientists' awareness of existing research, published or unpublished, depends upon his own position in its social organization, the size of the area, and the amount of agreement among researchers in the area about the labels they are using in defining their research. These factors also affect how rapidly he obtains information. In this type of "socio-scientific" communication interactions, speed is vital since unpublished research, when published could pre-empt his own discoveries. In the study of Narin and his colleagues[45] it has been shown that biomedical science field is not only exhibiting many important specialties but also that these specialties are continuously growing. This in turn is seen to affect the flow of relevant research information among biomedical scientists. Thus, the larger in size the research literature is in a given research orientation, the more difficult it is for an individual biomedical scientist in that given research orientation to obtain the relevant information.

Since it appears that scientists require materials outside their own areas, further understanding of how they

obtain this information would seem to be imperative if the communication of scientific research information is to be improved. This is even more important in the field of biomedical science, which is made up of two important segments with dynamic subspecialties - basic biomedical science and clinical medicine.

Classification of Biomedical Science Literature

Many agree that the traditional form of organization of knowledge has failed to keep up with the continuous proliferation of scientific specialization and the concomitant exponential growth rate of their literature.[46] These have been seen to have contributed to the submersion of the most useful and vital research information.

In an attempt to be all things to all knowledge, the three universally primary literature classification systems fail to bring like things together for the community of scientists, practitioners concentrated in a specific field. More serious a problem, is the failure of traditional classification systems to organize research journals and non-journal serials (the prime channels of dissemination of scientific knowledge) in a format that maximizes the exposure of relevant research literature to a defined scientific community. The tradition to dichotomize knowledge into "pure," "applied," "technology," and "practice" always invariably becomes anachronistic to newborn specialization. Thus, the growing desires and needs of scientific community to have maximum

contact with the ever growing pools of knowledge have led to a recent avalanche of number of studies seeking to address the problems of research information communication, and the general structure of science and its literature. Cozzens et al.[47] have collated these kinds of studies in their Citation Analysis: An Annotated Bibliography. Also, the Royal Institute of Technology Library, Stockholm's have made a comprehensive compilation of a bibliography of Bibliometrics and Citation Indexing and Analysis.[48]

The central question of whether methods used by the librarians, documentalists and information scientists to organize knowledge and information keep pace with the growth of knowledge and our changing construct of it have led to several innovative ideas in the overall conceptual theory of classification of knowledge. From Bradford's Law of Scattering to Goffman's epidemic theory of information has emerged the notion of a "core-knowledge" which generates other knowledge within the universe of science.[49, 50] Briefly stated, this "core-knowledge" concept consists of the tiny but active subdivision within the universe of scientific knowledge which generates laws and natural constants that aid the growth of science in general and technological developments in particular.

Since the classic work of Gross and Gross, 1927,[51] in which a tabulation of citations were used to analyze scientific literature there have been several other studies which show the complex nature of the structure of science. It

was Van Cott and Zavala,[52] applying the technique of factor analysis to subject classifications of abstracted articles in physics who observed that, "It should be possible to extract from the literature of a given discipline some relatively stable structure that reflects the true structure of that discipline." In the same year, Xhignesse and Osgood[53] studied the citation characteristics of the psychology literature and created a model showing well-defined clusters of journals. These early studies seem to lead to speculations that there may be other useful forms of classification such as the "research shell" classification of knowledge to be proposed in this study.

Narin and "Research Level" Classification Scheme

In Evaluative Bibliometrics: The Use of Publication and Citation Analysis in the Evaluation of Scientific Activities,[54] a study conducted by Narin and his colleagues for National Science Foundation, developed and classified the literature of biomedical science into four layers of "research levels":

Basic biomedical research;

Clinical investigation;

Clinical mix; and

Clinical observation.

These four research levels were acknowledged to represent the four research orientations within the universe of biomedical science with no formal definition of the terms.

Using biomedical journals as units of this classification, Narin and his colleagues found that the citation pattern of journals within a subject field reveals certain characteristics of the field and of its interrelations with other fields. Using this information, Narin classified a particular journal into one of the four research levels by its citation pattern. The resulting classifications were seen to reflect the type of research published therein. In the scheme, over nine hundred biomedical journals were classified into fifty biomedical fields and into four research levels ranging from the most applied (clinical observation) to the most fundamental (basic biomedical science). See Table I for the listing of biomedical science fields studied by Narin.

The range of subjects covered in a given journal extend from the specific focus of a narrowly defined research specialty. The classification of biomedical science journals into fields conforms to the designation of the medical specialties around which the literature has arisen.

Narin's concept of "research level" classification of biomedical science literature pictures the literature of biomedical science as consisting of hierarchical layers with basic biomedical research level forming the bottom layer and clinical observation research level as the uppermost layer. Thus, the interactions between and among the layers are seen as unidirectional in a plane. Narin's work has added a new significant dimension to our knowledge of

Table I

List of Subfields in Biomedical Science
Defined by Narin

Clinical Medicine

- General and Internal Medicine
- Allergy
- Anesthesiology
- Cancer
- Cardiovascular System
- Dentistry
- Dermatology & Venereal Diseases
- Endocrinology
- Fertility
- Gastroenterology
- Geriatrics
- Hematology
- Immunology
- Obstetrics & Gynecology
- Neurology & Neurosurgery
- Ophthalmology
- Orthopedics
- Arthritis & Rheumatism
- Otorhinolaryngology
- Pathology
- Pediatrics
- Pharmacology
- Pharmacy
- Psychiatry
- Radiology & Nuclear Medicine
- Respiratory System
- Surgery
- Tropical Medicine
- Urology
- Nephrology
- Veterninary Medicine
- Addictive Diseases
- Hygiene & Public Health
- Miscellaneous Clinical Medicine

Basic Biomedical Research

- Physiology
- Anatomy & Morphology
- Embryology
- Genetics & Heredity
- Nutrition & Dietetics
- Biochemistry
- Biophysics

Table 1, Continued

Virology
Parasitology
Biomedical Engineering
Mcroscopy
Miscellaneous Biomedical Research
General Biomedical Research

SOURCES: Narin, Frances. "Evaluative Bibliometrics: The Use of Publication and Citation Analysis in the Evaluation of Scientific Activity." A study done in fulfillment of Contract NSF C627 with National Science Foundation, March 1976.

classification of the biomedical science literature. However, to date it has not been shown that experts in these fields would agree with the classifications that were created by Narin using citation analysis. Since biomedical science experts know their fields and the literature generated and utilized by them, it is expected that they can create classification of the literature of biomedical science based on the concept of research orientations. One of the purposes of the present study is to attempt to validate the concept of the research level classification of Narin by comparing the research level classification with research shell classification to be developed by experts.

Narin's work undoubtedly brought to focus that there are differences between various research orientations within the universe of biomedical science as reflected in their pattern of citations. The establishment of research level classification aided the present study in addressing the nature and pattern of flow of research information within and across the different research orientations within the universe of biomedical science.

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CHAPTER THREE

CONCEPTUAL FRAMEWORK

Purposes of the Study

It has been noted earlier that, biomedical science exhibits many important and active subfields. These subfields, in terms of literature generated by them are dynamic and growing.[1] Molinowsky's classified list, categorized such important and active subfields in biomedical science.[2] Wagner in a provocative lecture, The Basic Medical Sciences, The Revolution in Biology and the Future of Medical Education, capsulized the dynamics of biomedical science in relation to biology.[3] The dynamics and the growth of the literature of biomedical science influence the flow of research information within and across various research orientations of biomedical science.

Previous studies sought to establish the relationship between one subject field and others in terms of their literature interactions. One of these studies introduced and established the concept of "research level"[4] in the study of the literature of biomedical science. However, none sought (1) to identify the pattern of flow of research information within and across various research orientations within the universe of biomedical science; and (2) to find the degree of interactions between them.

Biomedical science is a mosaic of more than fifty subfields,[5] which can be classified into definable research

orientations by using the biomedical science experts and the literature they generate. The universe of biomedical science research in this study shall be considered as made up of four research orientations, each to be designated as research shell.

Crane,[6] noting the literature interaction between various subject specialties recommended that further research is needed to identify how research information in one subject specialty interacts with research information in another subject specialty. No one will doubt that scientists in general and biomedical scientists and practitioners in particular require research information outside their own areas during the course of their research or professional investigation and practice. The main reasons they do so is to prevent any possible duplication of research efforts and to enhance efficiency in professional investigation and practice. Whether the benefits derived from referring to past research are directly proportional to the size of the available research literature has been questioned: "Although the size of the literature continues to increase, only a small portion of it appears to be of significant value."[7] Thus, it seems possible that the rapid growth in size in the quantity of research literature places greater resistance to the flow of quality and quantity of research information within and across research orientations. Therefore, there is a general need to understand the nature of the interaction between the literature of various research orientations within the uni-

verse of biomedical science. Any finding of relationship between the size of research literature and the quality of flow of research information within and across the different research orientations would aid in this understanding.

The general purposes of this study are:

(a) to examine the interaction between the literature of the various research orientations within the universe of biomedical science;

(b) to test the idea of classification of the research journals of biomedical science into research orientations by biomedical science experts;

(c) to validate the concept of using citation analysis to classify biomedical science research journals into "research level;"

(d) to determine the quantitative differences in the flow of research information between one biomedical science research orientation and the others; and

(e) to study the effect of the increase in the size of research literature on the quantity of flow of research information within and across research orientations.

The study of Narin and his colleagues, introduced a new but important dimension into the study of the structure of literature of biomedical science in particular. From the study, it can intuitively be viewed that biomedical science is made of hierarchical research level structure, which this study chooses to call research shell structure. The concept

of research level and research shell structures is basically the same because, research level and research shell structures refer to the different research orientations existing within the universe of biomedical science. However, while the concepts of research level structure emerged through examining the pattern of citation among the various subject fields within the universe of biomedical science, that of research shell structure was developed using biomedical science experts and the literature they generate. The objective of picturing the universe of biomedical science as made up of research shells is to address the problem of the nature of interaction between and flow of research information within and across research orientations. The use of research shell terminology in this study is only a matter of personal convenience of looking at the same structure of the universe of biomedical science. And also, a means of distinguishing it from research level structure.

As early as 1963, Garfield[8] asserted that citation indexing provided an objective method for defining a subject field. In the same year, Derek Price,[9] declared in an unpublished paper that the study of citation relationships among research documents might allow one to view the structure of science in geographic terms. These early theoretical assertions and declarations led to Kessler's study on "bibliographic coupling;"[10] and Small and Griffith's[11] two-part study of the structure of scientific literature in which they introduced the concept of co-citation to identify the interaction between one subject specialty and another.

These seminal ideas of using citation interrelationship to define the structure of science led Narin and his colleagues to develop the "research level" structure[12] of the literature of biomedical science. The structure of biomedical science was identified to consist of four hierarchical layers in which basic biomedical research forms the base of the hierarchy. Although they identified the different research orientations within the biomedical science and classified them into hierarchical structure ranging from the most basic research to most applied, the question of whether biomedical science experts can be used to classify the universe of biomedical science into defined research orientations was not examined.

While the operational definitions of Narin's four research levels were based on citation patterns, that of four research shells were based on defined guidelines used by the biomedical science experts in the classification. This led to a change of nomenclature (see Table II).

Since experts will be employed to classify the research journals in biomedical science into the various research orientations, definitions of each of the research orientations must be comprehensible to the biomedical science community.

Generally, it can be hypothesized that, the literature generated by basic biomedical science research is considered as the fundamental vehicle of biomedical science communication. Thus, basic biomedical science literature provides a

Table II: The Narin/Pinski "Research Levels" Classification Scheme Through Citations and the "Research Shells" Classification Scheme Through Biomedical Science Experts

"Research Level" Classification Nomenclature	"Research Shell" Classification Nomenclature
Basic Biomedical Research Research L4	Basic Biomedical Science Research Shell 1 (Nucleus)
Clinical Investivgation Research L3	Applied Biomedical Science Research Shell 2
Clinical Mix Research L2	Clinical Research Shell 3
Clinical Observation L1	Clinical Practice Shell 4

basis for the growth of the development of the literature of clinical medicine. In other words, basic biomedical science provides the nucleus which stimulates the growth of biomedical science as a whole. The biomedical science research journals will be used to classify the universe of the literature of biomedical science into research shells by the biomedical scientists and clinicians.

To classify the literature of biomedical science into "research shell" nomenclature, the following definitions guided the study:

Shell 1 - Basic Biomedical Science Research:
The first research shell is concerned with fundamental scientific research that may or may not lead to the advancement of medicine.

Shell 2 - Applied Biomedical Science Research:
The subject research area of biomedical science which is concerned with mission-oriented research activities that emphasize the applicability of certain existing research results to the understanding and solution of biomedical problems.

Shell 3 - Clinical Research:
The subject research area of biomedical science which is concerned with finding solutions to medical problems by direct or indirect experimentation on human subjects.

Shell 4 - Clinical Practice:

The subject area of biomedical science which is concerned with observation of medical facts of existing and on-going medical practice without drawing much inference from these observations.

An acceptance of the above definitions by biomedical science experts in classifying the biomedical research literature into their defined research shells will mean that scientific body of knowledge in general and the biomedical science in particular, can be demonstrated to have unique and different research shells.

The problem of understanding the structure and pattern of flow of research information within the biomedical science community has led to ask if a research shell within the universe of biomedical science generates streams of literature with quantifiable exchange of research information with other biomedical science research shells as demonstrated in the pattern of flow of citations. Thus, this study will address the connection between different research shells in the universe of biomedical science by examining the citations which flow within and across each research shell. The study will examine whether objective facts exist to support the flow of research information between the basic biomedical science research shell and those of clinical medicine; and whether the increase in the size of biomedical science literature actually contributes to decreasing the flow of

research information within and across the biomedical science research shells.

Specific Problem Statement

While previous studies seem to suggest that the growth of clinical medicine depends on the growth of basic biomedical science, an aspect of this general problem which has not been explored is the quantitative relationship between the flow of research information (citations) from the basic biomedical science research into that of clinical medicine research and the flow of research information from clinical medicine research into the basic biomedical science research.

This study will address the fundamental questions:

1. Can biomedical science experts effectively classify the biomedical science research literature into their research shells? Assuming that (1) is possible;
2. How does this classification compare to that of Narin, achieved through citation analysis?;
3. What is the quantitative difference in the flow of research information between the basic biomedical science research shell and the clinical medicine research shells; and
4. What is the effect of increase in size of research literature on the flow of research information?

The answers to these questions should be important to the field of information and biomedical science and librarianship in four ways. First, any finding showing that experts

can effectively classify the literature of biomedical science into their different defined research orientations may lead to a new theory of classification of scientific knowledge and hence lead to improved information retrieval system. Second, the knowledge of these quantitative relationships may help in understanding the problems associated with communication of scientific information within the biomedical science community. And third, the discovery of the existence of any relationship between the size of research literature and the flow of research information of biomedical science will fill a gap in our knowledge concerning biomedical science communication.

In general, this study will investigate the notion that the literature of basic biomedical science provides a basis for growth and development of the literature of clinical medicine, and hence that the growth and development of clinical medicine itself relies upon the growth and development of basic biomedical science.

The central hypotheses which will guide this study shall be:

H1: Biomedical science can be classified into defined research shells by biomedical science experts using research journals;

H2: This classification will correlate highly with that of Narin, achieved through citation analysis;

H3: The quantity of research information in the form of the number of references made from the basic

biomedical science research shell by any of the outer biomedical science research shells is significantly greater than that of other biomedical science research shells to the basic biomedical science research shell.

H4: Using Bradford's law of distribution, it can be shown that the flow of research information as measured by the number of reference counts from basic biomedical science research shell to the biomedical science research shells decreases significantly as the size of research literature in basic biomedical science increases.

The reasons for the hypotheses are:

Biomedical experts having a good knowledge of their field, will tend to be able to classify the universe of biomedical science into research shells using the biomedical science research journals, assuming that the concept is valid.

Basic biomedical science representing the source of biomedical research and its research orientation being mostly basic and fundamental, will tend to provide greater sources of research information than the clinical medicine research shells.

Clinical medicine, the three outer research shells of biomedical science representing the applied arm of the biomedical science will tend to rely significantly on research information of basic biomedical science.

The growing in size of research literature of basic biomedical science will tend to contain irrelevant research literature which affects the flow of relevant and important research information.

Arising from the above hypotheses are the following specific questions:

Can the universe of biomedical science actually be classified into research shells using research journals?

How will such a classification compare with that of Narin, accomplished through other means?

What is the quantity of "flow of research information" as measured by citation analysis from basic biomedical science research shell to other research shells?

What is the quantity of flow of research information as measured by citation analysis from any of the other research shells to basic biomedical science research shell?

How is the flow of research information as measured by citation analysis from basic biomedical science research shell into all the research shells affected by an increase of research literature in basic biomedical science?

Limitation of the Study

The study is limited to the quantitative analysis of the literature of biomedical science. As conventionally defined, the biomedical science literature shall include all documents classified as relating to basic biomedical science and clinical medicine research shells. Sociological

factors which may influence the nature of the flow of biomedical science are not considered. Also, the study does not consider the influence of the environments of the four biomedical science research categories within the universe of biomedical science in the generation of literature. That is, how clinical medicine and basic biomedical research environments affect the nature of productivity of literature is not considered in this study.

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CHAPTER FOUR

METHODOLOGY

Introduction

A number of different research methods are available which can provide a measure of understanding of the infrastructure of biomedical science and the nature of interactions of its subfields with one another. Some methods allow the examination of the nature of contribution that basic biomedical science makes to applied biomedical science innovations and others provide means for studying the relationship between basic biomedical science and clinical medicine through the analysis of citation in varying subject fields.

For instance, at an early stage of the study of the structure of science, the case study method was employed to examine the nature of the contribution of scientific research to technology. This method relies on an analysis of the historical lineage of specific technological innovations. Examples of research projects which have employed the case study method to advantage are Project Hindsight,[1] TRACES,[2] and Comroe and Dripps.[3]

Although this method has been used successfully to establish a pattern of relationship between science and technology, and between one subject specialty and another, case studies as a research method possess certain limita-

tions. The use of the case study method requires specialists who are capable of identifying and interpreting the nature of the infra-structure of science as revealed by the historical investigation. Also, one's ability to generalize is made difficult by a case study, and the development of comprehensive and complete case studies is extremely time consuming. These factors tend to limit the number of individual cases which can be investigated and in addition, they produce a rather high unit cost. Finally, many members of the scientific community are skeptical about the use of an historical analysis as a means of obtaining an accurate picture of the present. It has always been argued that the relationship between science and technology is so dynamic that the study of such relationship as it existed in the past often results in an inadequate description of the present.

Analyzing the nature of this interaction on real-time basis, Allen[4] developed an instrument which appears to hold some potential. He developed the use of critical incidents and Solution Development Records to monitor research projects which are in progress. In this method, it would allow the investigator to indicate in his own best judgment, the qualitative nature of the interaction.

As in the case of the case study method, the Solution Development Record does not only require a rather high expenditure in terms of time and money but also needs the active participation of the individual researcher.

Another instrument which has been employed in the study of the nature of the interaction of science and technology

is that of formal interview. Unfortunately, interviews and questionnaires are difficult to develop and administer. Also, response rates often endanger the validity of such studies. Summarizing some of the major disadvantages of interviews and questionnaires, Webb et al.[5] stated that they intrude as a foreign element into the social setting they describe; they create as well as measure attitude; they elicit atypical roles and responses; and they are limited to those who are accessible and will cooperate.

However, to study the substantive nature of the pattern of flow of basic biomedical science research information and of clinical medicine, citation analysis method was supplemented by the questionnaire method in this study. The reasons for the use of questionnaire method as a supplement to the citation analysis method were based on the facts that:

(1) The literature of the universe of biomedical science being the by-products of research activities within biomedical science community, biomedical scientists and practitioners are the best qualified to determine the research shell classification of each of the research literature. Questionnaire method was found most useful in obtaining the defined research shells.

(2) It was the only method which facilitated the collection of the right type of data - classification of research journals by the experts.

(3) It provided economy of effort and time.

The detail of how this method was used in part to obtain the

right type of data for this study is given later in the chapter.

Citation analysis is that area of bibliometrics which deals with the study of the relation between a part or the whole of cited documents and a part or the whole of the citing documents. Ziman rightly observed that "a scientific paper does not stand alone; it is embedded in the 'literature' of the subject."[6] Citation analysis method taken advantage of the scientist's obligation to recognize sufficiently another scientist's contribution. This obligation to recognize sufficiently another scientist's contribution has been expressed as follows:

> We know that he will be under pressure to make his contribution to knowledge known to other scientists and that they in turn will be under pressure to acknowledge his right to intellectual property.[7]

In the context of the nature of the flow of research information within the universe of biomedical science and clinical medicine, this recognition is usually achieved by a citation to published works.

Citation analysis studies have been based on all or some of the following assumptions with their supporting or counter validity:

(a) Citation of a document implies use of that document by the citing author. This assumption has two conditions: (1) the author refers to all, or at least the most important documents used in the preparation of his work; and (2) all

documents listed were actually used. Thus, author refers to a document only if that document has contributed to his work. Davies, stating a "fundamental law of reference giving" said, "it is unnecessary to have read or even seen the reference yourself before quoting it."[8] Price had also noted that:

> Clearly, the citing of a paper does not necessarily imply it has been read, and even more certainly not all papers read are cited, but there is some significance in such citations.[9]

It seems therefore that, without looking at the text of both the citing and cited documents, it may not be possible to make any judgement as to whether a particular citation does indeed represent use of materials in the cited document.

(b) Citation of a document reflects the merit (quality, significance or impact) of that document (author, journal or article. The study of Edwards and her colleagues showed that there is a high positive correlation[10] between the number of citations which a particular document receives and the quality of the document. Bayer and Folger noted that measures derived from citation counts have high validity.[11] However, Thorne[12] argues that citation counts have spurious validity because documents can be cited for reasons irrelevant to their merits. This assumption has been generally tested and has found supports in a number of studies including studies of scientific papers, journals and scholars.

(c) Citations are made to the best possible works. This assumption suggests that the citing author knows the

population from which the cited documents are selected. Assuming that citations are made to the best documents in the population, then one must imagine that authors sift through all of the possible documents that could be cited and carefully select the best. However, studies of research information use have suggested that accessibility is as important a factor as quality in the selection of information source. Soper in 1976[13] conducted an investigation on the effect of physical accessibility upon selection and use of references. She found that the largest proportion of documents cited in author's recent papers was located in personal collection; a smaller proportion was located in libraries.

(d) A cited document is reflected in the context to the citing document; if two documents are bibliographically coupled, they are related in context; and if two documents are co-cited, they are related in context. The successful use of citation indexes to retrieve relevant research information, given a cited document supports the first parts of this assumption. Barlup[14] conducted a study in which authors were asked to access the degree of relatedness of citation to their own works. The authors judged that 72% of such citations were related. However, with the second part of the assumption, Martyn[15] contends that a bibliographic coupling is not a valid unit of measurement because one does not know that two documents citing a third are citing the identical unit of information. Thus, bibliographic coupling is merely

an indication of probability of relationship. The same argument in fact applies to all uses of citations.

(e) All citations are equal in all respects. In recent years, many investigators have sought ways to refine citation analysis which would not necessarily treat all citations to the same articles as equivalent. A number of recent studies have shown that it is not wholly valid to treat all citations equally. Bertram[16] in his study reported that there is a significant relationship between citation level and the section of the citing article in which a citation occurs. A study reported by Herlach[17] tested and accepted the hypothesis that mention of a given reference more than once within the same research paper indicates a close and useful relationship of citing to cited paper. Voos and Dagaev[18] agreed that location and multiple mention can be used to distinguish citations of particular value.

Walhart[19] succinctly summarized another limitation of citation analysis method when he noted that it relies on printed documents - particularly in the form of journal articles as the basic source of data. Such reliance limits an investigator to the study of only those communication patterns of persons who publish as well as only those communication acts which involve the use of documents. It has been observed throughout the history of scientific communication that others do make references to personal conversations.

Obviously then, citation analysis permits only a limited view of the total communication system and of the nature of

ical areas or institutional settings, since what one is actually analyzing are published literature articles of research and development, and not the research and development process itself;

(c) Citation analysis can be accomplished without the assistance of highly trained subject specialists;

(d(Citation analysis can be performed at a fraction of the cost of the other methods discussed above, thus providing the investigator with the means for examination of much wider range of cases; and

(e) With the development of science citation index and social science citation index in computer form, the problem of manual compilation of data has been eliminated.

Of the research methods which can be used to study the nature of interaction of the literature of science, most especially the literature of biomedical science, citation analysis provides the best compromise. Insofar as the present study is concerned, and considering time limit, the purpose of this study, the capabilities of this investigator to handle and manipulate effective substantive elements, and related resources and costs, citation analysis method would be the research method for this study.

The central purpose of this study is to study the interaction between the literature of basic biomedical science and that of clinical medicine in terms of their flow of research information. To realize this purpose, selection of samples from the universe of biomedical science

research journals was undertaken, the classification of the research journals into research shells was developed and, an input-output citation matrix table was constructed.

Selection of Samples

The quality of literature generated by the four research shells of biomedical science is phenomenally large and it is realistically impossible to undertake an analysis of the entire body of such knowledge. An examination of the data of source items, the number of journals indexed and their corresponding number of citations generated which are compiled annually by the Institute for Scientific Information since 1968 demonstrates this fact.[21] In order to reduce the universe into a manageable study, and still retain a generalizable result, the study uses Science Citation Index's Journal Citation Reports: 1980[22] to develop and compile the data for the study.

The Journal Citation Reports, which from now on will be called simply as JCR is a recent volume addition to Science Citation Index (SCI). It started publication in 1975 and has since been coming out annually with new, revised, and updated information. The JCR has some features which make it amenable for easy bibliometric study of this nature. Some of these features include:

(1) The JCR is an index containing journal ranking packages with eight listings:

(i) Each volume contains listings of the scientific journals in alphabetical order cited in that year.

(ii) It contains the listings of several highly cited non-journal publications;

(iii) The next five of the listings contain the ranking of journals by various counts and indicators such as immediacy index and half-life; and

(iv) the last listing contains the ranking of journals by impact factor within subject categories.

Impact factor was defined by Garfield as "a measure of the frequency with which the 'average cited article' in a journal has been cited in a particular year." The JCR impact factor is basically "a ratio between number of citations and citable items published."[23]

The ranking listings present a great deal of useful information. Some of these are summation of reference counts made and citations received which are broken down by cited journals and by citing journals in the two large sections of the JCR called the citing and cited journal packages.

The citing and cited journal packages show citation frequency relationship between pairs of journals. Thus, in the citing journal package, one can find which journals a particular journal has cited, and a distribution by year of the publication dates of the cited materials.

In the cited journal package, one can find which journals have cited a particular journal, and a distribution by year of the publication dates of the cited materials. Specimens A and B, reproduced from the JCR (1980)[24] illustrate the arrangement of these useful packages.

SPECIMEN A

SCI JOURNAL CITATION REPORTS

CITING JOURNAL PACKAGE

IMPACT	CITING	JOURNAL CITED JOURNAL	TOTAL	1980	1979	1978	1977	1976	1975	1974	1973	1972	1971	REST
			<-NUMBER OF TIMES THIS YEAR WAS CITED IN 1980->											
5.71	J BIOL CHEM		61133*	1788	6924	7807	7037	5726	4870	4101	3226	3001	2453	14200
5.71		J BIOL CHEM	13403	688	1849	1586	1431	976	1023	733	630	562	511	3414
8.77		P NATL ACAD SCI USA	4329	111	633	775	690	412	380	307	224	211	102	484
4.67		BIOCHEMISTRY-US	3812	90	377	451	435	414	327	288	244	179	252	755
2.86		BIOCHIM BIOPHYS ACTA	3173	43	245	346	323	339	219	205	242	195	154	863
2.96		BIOCHEM BIOPH RES CO	2119	38	209	248	300	246	196	188	131	130	100	333
3.19		BIOCHEM J	1708	15	117	181	136	141	92	104	105	63	69	685
6.49		NATURE	1705	56	202	233	174	132	121	83	22	23	23	636
3.60		EUR J BIOCHEM	1675	19	142	271	217	216	158	176	125	75	64	206
5.68		J MOL BIOL	1300	10	97	86	172	124	130	114	111	92	60	304
2.51		ARCH BIOCHEM BIOPHYS	1290	29	131	111	123	131	89	97	84	77	54	364
1.64		METHOD ENZYMOL	1242	14	74	106	63	29	42	142	16	170	102	484
2.20		ANAL BIOCHEM	1168	24	92	123	93	206	107	103	50	60	59	251
2.97		FEBS LETT	1060	22	192	205	151	120	96	81	60	48	43	42
14.39		CELL	882	40	180	239	190	132	59	38	0	0	0	4
5.70		SCIENCE	739	18	58	96	86	45	55	51	42	64	25	199
9.74		J CELL BIOL	637	24	90	92	56	44	58	53	39	22	31	128
5.16		J AM CHEM SOC	631	11	38	36	34	30	26	25	16	17	28	368
2.60		J BACTERIOL	562	14	64	66	61	63	40	48	36	28	28	114
.38		FED PROC	557	58	155	123	48	50	21	30	12	5	2	53
24.90		ANNU REV BIOCHEM	551	13	90	86	95	100	56	47	13	13	9	29
6.87		J CLIN INVEST	481	9	46	69	63	43	57	25	27	22	19	203
2.00		J BIOCHEM-TOKYO	447	7	48	55	47	26	43	44	26	27	11	113
4.70		ENDOCRINOLOGY	380	11	71	50	43	26	22	36	24	21	9	67
5.07		NUCLEIC ACIDS RES	357	17	93	89	78	38	27	15	0	0	0	0
1.39		ANN NY ACAD SCI	340	4	0	36	9	7	40	29	16	6	10	183
4.32		J VIROL	299	9	34	46	44	46	33	21	24	22	7	13
5.04		MOL PHARMACOL	252	11	46	30	37	42	13	14	6	8	5	40
3.73		J LIPID RES	251	7	31	26	25	20	10	8	15	11	13	85
3.42		VIROLOGY	247	6	29	26	27	18	18	20	17	15	8	63
4.13		CANCER RES	219	4	23	36	39	24	10	11	7	15	4	44
2.95		EXP CELL RES	201	5	11	25	29	19	15	16	14	15	7	45
6.41		J IMMUNOL	200	6	19	29	22	36	33	8	7	2	5	33
4.77		COLD SPRING HARB SYM	199	2	26	39	11	6	10	8	5	21	15	56
2.88		MOL GEN GENET	195	2	34	27	34	34	21	12	12	11	4	4
		ENZYMES	191	0	0	.	0	10	30	28	21	18	29	54
2.42		H-S Z PHYSIOL CHEM	186	1	10	16	20	28	20	8	11	16	10	46
2.78		AM J PHYSIOL	184	8	17	33	15	13	14	6	2	16	10	50
8.11		ADV ENZYMOL RAMB	178	1	21	16	9	3	14	16	22	7	6	63
3.42		J SUPRAMOL STRUCT	168	4	25	46	42	12	6	8	24	4	6	32
3.18		J CELL PHYSIOL	166	1	13	26	32	27	18	7	10	8	4	20
2.45		BIOCHEM PHARMACOL	164	2	24	18	16	15	17	13	17	8	7	27
10.65		J EXP MED	156	3	13	22	15	13	13	8	8	4	6	51
1.75		CAN J BIOCHEM	155	2	28	24	17	12	16	4	15	12	9	16
3.33		ANAL CHEM	148	0	0	0	4	2	2	4	3	0	4	129
		NATURE-NEW BIOL	146	0	0	0	0	1	0	1	59	40	45	0
9.34		ADV CYCLIC NUCL RES	144	0	22	24	38	2	36	9	8	5	0	0
3.24		J NEUROCHEM	140	3	24	19	12	21	9	7	23	24	2	24
3.63		J PHYSIOL-LONDON	129	1	4	13	11	9	9	7	11	13	2	46
3.73		LIFE SCI	122	0	23	27	12	18	12	11	3	2	3	11
14.21		NEW ENGL J MED	111	2	9	21	18	16	6	10	2	4	8	15
7.25		ADV PROTEIN CHEM	109	0	1	2	15	8	5	4	12	5	0	57
3.53		DEV BIOL	109	1	16	18	14	11	8	5	7	5	10	14
4.03		J GEN PHYSIOL	108	2	3	3	9	11	3	7	2	2	12	54
1.35		P SOC EXP BIOL MED	107	1	2	7	11	2	14	1	5	10	1	53
2.12		J CHROMATOGR	106	3	11	12	7	4	2	9	4	11	6	37
3.14		J MEMBRANE BIOL	100	1	7	13	19	4	12	8	7	14	5	6
3.98		J CYCLIC NUCL RES	92	0	18	30	29	8	7	0	0	0	0	0
14.41		PHYSIOL REV	85	0	6	14	16	6	2	3	9	2	1	26
5.94		BLOOD	82	5	14	14	10	7	5	3	1	1	2	20
3.74		BRAIN RES	79	5	8	13	17	7	8	8	4	4	2	3
7.76		CURR TOP CELL REGUL	79	4	4	11	7	13	2	11	3	17	3	4
2.74		J LAB CLIN MED	79	1	1	4	6	10	4	2	11	4	2	34
4.51		DIABETES	77	7	14	9	7	5	6	5	0	8	8	11
		BIOCHEM Z	75	0	0	0	0	5	0	0	0	0	0	75
4.07		J CLIN ENDOCR METAB	73	2	13	10	9	5	6	8	5	3	5	7
1.55		MOL CELL BIOCHEM	73	1	7	10	11	14	15	5	9	0	0	1
		ACTA CHEM SCAND	70	0	0	0	0	3	0	0	0	4	2	61
1.64		BIOCHIMIE	66	0	6	11	7	8	5	12	8	5	4	0
		METHOD ENZYMAT AN	66	0	0	3	0	0	1	44	0	0	2	19
1.97		J ORG CHEM	63	0	4	5	4	4	5	0	2	4	5	30
1.74		J STEROID BIOCHEM	63	2	19	5	7	11	8	2	3	3	0	3
6.72		*PROG NUCLEIC ACID RE*	62	0	6	2	4	15	4	4	6	9	2	11
		CAN J BIOCHEM PHYSIO	61	0	0	3	0	0	0	0	0	0	0	61
1.64		CARBOHYD RES	61	1	6	13	6	7	7	6	2	1	3	12
3.32		METABOLISM	61	0	6	14	2	12	6	3	5	0	4	11
3.53		PROSTAGLANDINS	61	4	8	13	17	8	2	3	3	3	0	0
1.68		CLIN CHIM ACTA	59	0	3	2	6	4	6	3	2	3	2	28
3.28		J PHARMACOL EXP THER	59	1	3	9	7	2	4	2	3	3	2	23
2.02		THROMB RES	58	2	10	9	9	9	8	11	0	0	0	0
8.84		ACCOUNTS CHEM RES	57	0	6	8	12	5	11	4	1	7	1	2
4.69		RECENT PROG HORM RES	56	0	4	3	2	7	4	10	4	2	4	16
2.22		BIOPOLYMERS	54	1	7	4	11	6	2	3	4	2	1	13
1.71		ADV ENZYME REGUL	53	1	3	3	7	12	0	1	8	5	2	11
		BACTERIOL REV	52	0	0	0	10	9	9	6	5	2	1	10
		FLAVINS FLAVOPROTEIN	52	7	1	2	1	30	0	0	0	0	6	5
2.16		J PHYS CHEM-US	52	0	2	3	1	0	1	3	4	4	1	33
2.41		GENETICS	51	0	5	4	10	4	1	8	4	4	1	10
		BIOCHEM SOC TRANS	50	1	11	8	7	10	6	3	4	0	0	0
5.09		CIRC RES	50	0	2	2	3	10	3	16	2	2	2	8
2.66		INFECT IMMUN	50	3	10	5	11	8	4	2	4	2	1	0
		ALL OTHER (2647)	9140	268	892	1159	1045	875	801	549	443	448	368	2292

SPECIMEN B

SCI JOURNAL CITATION REPORTS

CITED JOURNAL PACKAGE

	CITED JOURNAL / CITING JOURNAL	TOTAL	1980	1979	1978	1977	1976	1975	1974	1973	1972	1971	REST
5.71	J BIOL CHEM	113670*	1799	9392	9778	9344	7097	7597	6032	5130	4725	4281	48495
5.71	J BIOL CHEM	13403	688	1849	1586	1431	976	1023	733	630	562	511	3614
2.86	BIOCHIM BIOPHYS ACTA	6802	52	434	577	665	454	517	412	340	331	295	2725
4.67	BIOCHEMISTRY-US	4182	44	442	433	376	343	317	303	248	221	178	1279
3.19	BIOCHEM J	2957	18	214	261	220	180	199	181	142	108	117	1317
2.96	BIOCHEM BIOPH RES CO	2933	122	397	315	250	198	201	119	131	109	119	973
3.60	EUR J BIOCHEM	2811	13	251	285	274	190	224	164	150	161	121	978
	P NATL ACAD SCI-BIOL	2791	109	462	388	363	167	223	140	118	112	100	629
2.51	ARCH BIOCHEM BIOPHYS	2574	28	212	217	204	169	182	140	161	117	108	1096
2.97	FEBS LETT	2004	67	274	187	173	140	130	91	89	75	80	599
2.00	J BIOCHEM-TOKYO	1671	17	78	96	103	94	107	100	96	77	69	859
2.60	J BACTERIOL	1426	18	88	79	100	70	103	92	65	78	69	944
2.20	ANAL BIOCHEM	1145	19	78	55	50	54	81	48	40	48	51	821
2.45	BIOCHEM PHARMACOL	1123	2	43	86	79	72	54	49	39	40	29	630
4.70	ENDOCRINOLOGY	1121	9	76	105	111	101	92	76	64	54	38	595
24.90	ANNU REV BIOCHEM	1068	10	182	169	132	87	86	65	53	41	30	213
3.14	J NEUROCHEM	959	2	43	68	90	41	66	45	39	35	36	494
3.78	AM J PHYSIOL	835	4	52	85	60	62	55	52	44	31	32	356
4.13	CANCER RES	824	12	61	59	66	62	52	53	32	29	19	379
6.49	NATURE	761	34	166	111	114	54	53	28	34	18	20	139
9.74	J CELL BIOL	755	19	120	99	81	53	66	44	33	28	41	111
6.87	J CLIN INVEST	712	21	69	86	59	42	55	48	25	32	28	247
1.12	INT J BIOCHEM	698	2	27	36	41	35	47	32	35	30	30	583
1.64	METHOD ENZYMOL	686	0	22	28	63	50	53	41	38	48	40	303
14.39	CELL	669	28	159	102	89	44	62	33	21	28	16	87
1.75	CAN J BIOCHEM	657	10	39	69	46	39	43	45	32	47	35	252
1.02	COMP BIOCHEM PHYS B	652	1	11	21	28	21	31	31	35	25	30	418
5.68	J MOL BIOL	625	9	62	52	68	42	63	53	44	34	32	199
5.07	NUCLEIC ACIDS RES	606	18	113	70	95	58	45	39	37	33	18	150
3.73	LIFE SCI	600	5	43	47	45	33	31	24	20	21	14	308
1.12	AGR BIOL CHEM TOKYO	577	1	12	16	17	15	27	20	18	27	18	405
2.42	H-S Z PHYSIOL CHEM	554	10	51	43	47	35	25	26	22	29	21	245
1.74	J STEROID BIOCHEM	536	1	18	33	56	33	44	47	46	19	24	215
.40	ADV EXP MED BIOL	532	2	32	45	49	43	36	35	27	23	26	214
5.16	J AM CHEM SOC	521	17	35	31	26	32	39	45	32	24	12	228
.88	PHARMACOL THER	488	2	19	47	40	34	28	26	18	21	11	220
3.74	BRAIN RES	474	0	20	30	42	30	28	15	9	15	19	268
1.62	J NUTR	469	0	4	17	12	17	15	17	15	13	12	347
5.04	MOL PHARMACOL	466	9	43	53	57	55	23	27	18	9	15	151
3.73	J LIPID RES	452	5	32	37	40	14	14	30	22	19	16	345
2.84	PLANT PHYSIOL	447	1	25	19	27	20	30	14	17	25	23	246
3.18	J CELL PHYSIOL	441	2	38	39	49	40	40	38	35	21	16	129
1.39	ANN NY ACAD SCI	438	27	74	94	69	42	33	23	19	10	9	98
1.55	MOL CELL BIOCHEM	430	7	66	54	44	38	29	22	24	12	13	121
.38	FED PROC	420	2	85	65	46	30	30	21	13	14	13	101
5.70	SCIENCE	416	18	72	66	50	33	34	18	16	13	14	82
5.41	J IMMUNOL	407	3	51	21	39	27	40	18	14	12	15	167
2.95	EXP CELL RES	386	5	24	34	43	29	33	36	16	17	14	135
.29	INDIAN J EXP BIOL	378	0	0	4	3	2	10	1	4	1	4	349
4.32	J VIROL	374	7	54	35	56	32	41	19	18	10	7	95
1.95	LIPIDS	346	0	20	15	19	9	10	14	12	11	6	237
2.02	THROMB RES	328	3	29	26	23	33	27	19	24	14	11	118
4.66	INFECT IMMUN	322	2	36	33	32	11	21	15	10	10	19	293
4.51	DIABETES	316	6	57	42	28	21	23	19	7	11	17	85
.01	BIOCHEMISTRY-USSR*	311	0	1	5	12	19	12	27	18	19	19	179
1.68	CLIN CHIM ACTA	300	2	8	12	18	13	14	12	8	18	6	189
3.28	J PHARMACOL EXP THER	300	2	23	22	15	19	16	12	7	10	9	145
3.53	DEV BIOL	299	1	22	39	36	28	37	13	11	9	10	93
4.07	J CLIN ENDOCR METAB	295											
2.12	J CHROMATOGR	292	1	16	17	7	7	15	10	10	13	12	184
1.80	J GEN MICROBIOL	286	1	5	10	15	8	18	16	12	15	9	177
.84	EXPERIENTIA	283	0	6	18	13	10	10	12	13	14	14	167
2.88	MOL GEN GENET	280	7	27	23	41	12	30	13	12	14	11	88
7.76	CURR TOP CELL REGUL	271	1	39	38	25	17	27	11	19	16	12	72
3.42	VIROLOGY	270	3	27	35	42	22	20	7	12	9	17	76
1.29	PHYTOCHEMISTRY	268	0	3	7	3	10	9	10	4	10	8	204
9.34	ADV CYCLIC NUCL RES	264	1	28	33	47	28	31	15	18	13	11	44
4.71	CRC CRIT R BIOCHEM	261	0	9	26	42	24	33	30	23	22	9	39
5.94	BLOOD	259	6	31	28	32	11	12	11	11	6	9	102
2.04	ARCH MICROBIOL	255	0	5	10	13	9	8	13	18	7	8	164
.18	ACS SYM SER	254	0	15	26	20	13	21	24	20	10	13	92
.59	SEIKAGAKU	254	12	60	33	37	25	17	21	7	9	7	26
14.41	PHYSIOL REV	237	1	6	27	30	35	23	22	14	16	13	50
1.64	BIOCHIMIE	233	0	20	17	17	16	19	18	8	13	12	93
2.89	MOL CELL ENDOCRINOL	233	4	34	36	24	20	14	14	7	9	9	55
.23	VOP MED KHIM	232	0	0	5	6	9	11	12	15	11	7	160
1.87	TRENDS BIOCHEM SCI	228	12	38	33	18	12	13	3	5	6	6	80
2.94	CLIN CHEM	226	1	16	5	10	11	15	8	4	9	9	138
2.35	AM J CLIN NUTR	223	3	7	11	6	9	11	11	7	6	5	147
.40	INDIAN J BIOCHEM BIO	223	0	1	3	4	2	13	9	5	9	5	172
1.64	CARBOHYD RES	222	1	19	13	16	5	12	9	9	9	11	124
3.24	J MEMBRANE BIOL	221	0	27	24	26	20	30	10	6	6	8	64
3.32	METABOLISM	220	0	6	14	14	11	14	14	10	17	11	109
1.78	TOXICOL APPL PHARM	217	2	9	6	10	14	9	8	6	7	1	146
1.33	J THEOR BIOL	216	0	14	21	20	17	17	17	17	16	11	66
1.55	INT J PEPT PROT RES	213	2	14	9	10	17	4	10	11	7	19	110
5.03	INT REV CYTOL	209	0	14	32	27	22	13	11	17	8	14	51
1.10	CAN J MICROBIOL	205	0	3	5	2	7	12	10	4	6	6	150
1.72	MOL IMMUNOL	204	0	10	9	14	10	14	10	13	10	13	99
.93	BIOORG KHIM	196	0	8	23	14	9	17	12	13	10	7	83
	BIOCHEM INT	188	7	22	8	12	4	14	11	11	6	6	82
.97	CHEM PHARM BULL	188	0	3	4	13	4	7	9	10	5	5	128
2.52	BIOL REPROD	185	3	12	15	7	19	12	10	13	4	4	86
3.15	PEDIATR RES	184	1	3	10	12	7	7	5	6	8	4	121
2.95	J MOL CELL CARDIOL	181	2	11	18	19	12	17	12	6	8	10	44
9.02	MICROBIOL REV	181	0	15	24	27	14	19	11	11	7	12	45
2.14	ACTA ENDOCRINOL-COP	175	0	6	11	9	16	13	4	17	10	6	81
2.31	ATHEROSCLEROSIS	175	0	7	6	15	0	4	11	7	10	3	110
1.04	HORM METAB RES	173	0	8	11	7	13	8	7	7	8	12	92
3.02	J NATL CANCER I	173	0	8	11	13	15	8	8	4	3	5	98
	ALL OTHER (1548)	34079	208	1759	2282	2107	1802	1919	1600	1322	1286	1165	18623

Biomedical science journals rather than books are sources of the data. Biomedical science research journals are chosen for the sources of the data because, traditionally between 80% - 90% of medium of biomedical science research communication have been reflected in journal literature and personal contacts. Rogers and Adams in 1950,[25] using the holding of the National Library of Medicine, studied the quantitative ratio of periodical literature to books. Their finding of 92% representing the periodical literature as medium of biomedical science research communication summarizes this fact.

A complete knowledge of the number of journals published and indexed in a given year cannot easily be assessed. This is because of the continuous exponential growth of biomedical science literature generated from the ever increasing number of specializations. While many new journal titles are being established, some old ones cease to exist. Gottschalk[26] and Barr[27] observed the "birth" and "mortality" characteristics of scientific journals when in their respective reports noted that 33% of the titles in the third edition of World List of Scientific Periodicals were dead and that 40% in the fourth edition were dead. Due to the problems of having an up-to-date information on the number of journal and non-journal serials titles that still exist and those that had ceased to exist, it is difficult to give an exact number of biomedical science research journals being published. However, a direct count of the number of journals and non-jour-

nal serials published and listed under medical sciences in Ulrich's International Periodical Directory 1980/81[28] puts the number at about 4,500; the Medical Literature Analysis and Retrieval System (MEDLARS) of the National Library of Medicine[29] stores the contents of over 3,000 journals; Excerpta Medica Lists of Biomedical Science Journals Abstracted in 1980[30] put the number at about 3,800; and while the Institute for Scientific Information's List of Biomedical Science Source Journals in 1980 gave the number indexed in the data base as about 2,000.[31]

An estimated over 500 publicly available bibliographic data bases contain more than 70 million citations spanning almost every scientific field.[32] Out of these number of citations, a conservative guess of about a third comes from the field of biomedical science. Equally, an examination of the Science Citation Index's Journal Citation Reports, 1980 reveals that there are over 500,000 source articles in 1980. These source articles produce over eight million citations in the given year and over a third of these belongs to biomedical science field.[33]

Since it would be difficult to handle such mammoth amounts of data, Bradford's concept that a few research journals account for many articles or citations,[34] was used to define a manageable population for this study. Only a small number of research journals within any given subfield account for high number of citations. Thus, the journals included in the present study were the most highly cited journals within the subfield. By the act of citing the jour-

nals, the scientists themselves consider them the most productive research journals in the field. The least number of citations per year in a given journal in a particular subfield was found to be ⩾ 500. The journals with these high level of citations are traditionally referred to as the "core-research journals."

Using the JCR, 1980 edition, and its journal citation ranking package,[35] three hundred fifty were identified to represent the core-research journals of the universe of biomedical science journals. This number accounted for only about 17.5% of the total number of biomedical science research journals indexed in the JCR 1980 from about fifty subfields. Illustrating the idea of core-research journals, an analysis of the three hundred fifty highly cited research journals revealed that they generated over 80% (see Table III) of the total number of citations.

Table III: The Ratio of Citations From 350 Core-Research Journals to Citations From 2000 Biomedical Science Research Journals Indexed in Journal Citation Reports (1980)

Number of citations from 350 highly cited journals C	Number of citations from 2000 biomedical journals indexed in JCR (1980) U	$\frac{C}{U} \times 100$
2,585,824	3,131,801	82.56

Table IV illustrates the names of the biomedical science subfields and as they are defined in the JCR and the number of journals in each subfield selected for study.

The process of selecting the total of three hundred fifty core-research journals from forty biomedical science subfields were carried out by examining the journal titles listed in the JCR, 1980 Source publications, and the Journal Citation ranking package. This package of the JCR arranges the journals and ranks them according to the number of citations in a year. In this way, the JCR makes it easy to identify the most highly cited research journal in any given subfield.

Classification of Research Journals Into Research Shells

The first purpose of this study is to develop a guideline used to determine whether biomedical science experts can classify the biomedical science research journal into defined research shells. The use of experts to identify categories of research articles, rating of research papers in biomedical science research literature, and identifying differences between basic research and applied research is not new in literature. Price has used the concept of "hardness" and "softness" to show that there are differences between basic science and technology in terms of the structure of literature generated and used by them.[36] Henry Small, in his unpublished paper, "Application of Biblio-

Table IV: Biomedical Science Subfields as Defined by Journal Citation Reports and the Number of Core-Research Journals Selected for Classification in the Present Study

BIOMEDICAL SCIENCE SUBFIELDS	Number of Journal Titles Per Subfield	Number of Core Journals Selected for Classification
Allergy	6	5
Anatomy and Morphology	18	5
Anesthesiology	10	5
Biochemistry and Molecular Biology	88	22
Biophysics	28	6
Cancer	33	10
Cardiovascular System	43	8
Cell Biology, Cytology and Histology	50	12
Dentistry	28	5
Dermatology and Venereal Diseases	14	6
Embryology	10	6
Endocrinology	35	10
Gastroenterology	17	6
Genetics and Heredity	53	12
Geriatrics and Gerontology	9	4
Hematology	21	8
Hygiene and Public Health	39	10
Immunology	48	11
Microbiology	47	11
Microscopy	11	5
Medicine - General and Internal	129	30
Neurology and Neurosurgery	79	13
Nephrology	5	2
Nutrition and Dietetics	22	5
Obstetrics and Gynecology	27	9
Ophthalmology	21	10
Orthopedics	11	5
Otorhinolaryngology	13	5
Parasitology	15	5
Pathology	39	10
Pediatrics	30	9
Pharmacology	60	12
Pharmacy	46	6
Physiology	36	10
Psychiatry	40	9
Radiology and Nuclear Medicine	44	10
Respiratory System	17	5

Table IV (continued)

BIOMEDICAL SCIENCE SUBFIELDS	Number of Journal Titles Per Subfield	Number of Core Journals Selected for Classification
Rheumatology	8	4
Surgery	59	10
Tropical Medicine	10	4
Urology	11	5
Virology	11	5
	1341	350

metric Methods to the Analysis and Tracing of Scientific Discovery,"[37] selected research articles in biomedical science field and gave them to biomedical science experts to classify them into basic biomedical research and clinical research. In the same vein, Comroe and Dripps[38] asked biomedical science experts to identify the top ten cardiovascular pulmonary research works between 1945-1975; and Virgo[39] used judges' ratings of biomedical science literature to examine the correlation between the high/low rated post graduate programs and their citation rates.

To test the hypothesis that Biomedical Science can be classified into defined research shells by biomedical science experts using research journals, the employment of biomedical science experts was required. In employing the knowledge of experts for the purpose of classification, a Guideline to Biomedical Scientists and Practitioners was developed giving the definitions of research categories of biomedical science research journals. The following definitions were used:

Basic Biomedical Science Research Journal - a journal that reports basic scientific research leading to the discovery of medical phenomena.

Applied Biomedical Science Research Journal - a journal that reports mission-oriented research activities emphasizing the applicability of certain existing research results to the understanding and solution of biomedical problems.

Clinical Research Journal - a journal that reports current research activities dealing with finding solutions to medical problems by direct or indirect experimentation on human subjects.

Clinical Practice Journal - a journal that reports only observational medical facts as they concern existing and ongoing medical practices without drawing any inferences from them.

The three hundred fifty biomedical science research journals were distributed into their various biomedical science subfields using the JCR Source Publications[40] which is arranged by Subject Categories. In this way the research journals were arranged into forty pre-selected biomedical science subfields. There are about fifty biomedical science subfields. Forty subfields were chosen for this study because the School of Medicine of Indiana University, in whose faculty, researchers, and medical doctors were used to classify the research journals into the research shell categories does not have defined departments in the subfields not chosen. Moreover, the ten biomedical subfields not included in the study are not likely to affect the overall result of the study because the three hundred fifty research journals representing the population accounted for over 80% of the total number of biomedical science journal citations in the given year.

Using the Faculty Directory of the School of Medicine of Indiana University,[41] a list of about three hundred bio-

medical scientists from forty biomedical science subfields were made. Three biomedical scientists were randomly selected from each of the subfields (departments). The guideline with the list of the selected research journals in each biomedical science subfield were hand distributed to the three experts in the subfield. One hundred twenty guidelines with the list of journals were distributed.

Biomedical scientists in this study means, all those members of any faculty of medicine and other related subject fields such as biology, chemistry, or physics whose areas of research could lead to advances in biomedical science; research fellows in the school of medicine and the medical doctors who have direct relations with the School of Medicine.

In order to identify whether the guideline (see Appendix B) and the questions were clear and comprehensive, it was pre-tested with twenty-one biomedical scientists and practitioners in and around the area of study. The twenty-one experts were randomly selected from the list prepared using the telephone directory[42] of the clinical practitioners, and departmental directories of the subfields in Indiana University at Bloomington.[43] The biomedical science subfields in which three experts were selected for the pre-test included:

1. Anatomy
2. Biochemistry
3. Microbiology

4. Physiology
5. Obstetrics and Gynecology
6. Anesthesiology
7. General and Internal Medicine

From the returns of the pre-test, the guideline was modified to reflect the issue raised by some of the experts concerning "overlaps" of research articles published in journals. A statement concerning overlaps was included in the final guideline and questionnaire (see Appendix B).

Validation of Research Level Classification Scheme

As noted earlier, the problem of classification of biomedical science literature into different research levels was undertaken by Narin and his colleagues[44] in which they developed the research level classification scheme using citation patterns of the research literature. One of the general purposes of the present study is to attempt to validate the idea of the existence of research level classification which was developed by Narin and his colleagues using citation interrelationships in the research journals. To do this the table of the number of research journals classified as belonging to basic biomedical science research shell which correspond with those of basic biomedical research level were compared. Also, those of applied biomedical science research shell were compared with those of clinical investigation research level; those of clinical research shell were

compared with those of clinical mix; and those of clinical practice shell were compared with those of clinical observation. The results of this comparison are discussed in Chapter Five.

Criterion for the Inclusion of a Classified Research Journal in the Study

The criterion for including a classified research journal in the final study was that two or more of the experts in a subfield gave the given journal the same classification. That is, in the case where a given journal had three different classifications by the three experts, that journal was excluded from the final study. Of the three hundred fifty journals, thirty-six journals were excluded from the final study (see Appendix D).

After the elimination of journals for which the experts did not agree, a list of the remaining three hundred fourteen journals in the four research shells was prepared. From the defined population, a stratified method of sampling[45] was used to randomly select one hundred fifty journals from the four research shells. The stratified method enables one to have correct proportion of randomly selected samples from the stratified population. In this kind of sampling, the population is divided into a number of nonoverlapping subpopulations called strata, to which certain portions of the total samples are located. Table V illustrates the number of journals in each research shell and the number selected using stratified method.

Table V: Research Shells and Their Core Research Journals

Research Shells	S_1	S_2	S_3	S_4	Total
Number of Journals in each Research Shell	105	84	73	52	314
Number of Journals Randomly Selected	50	40	35	25	150
% of Random Selection From Each Research Shell	33.44	26.75	23.25	16.56	100%

Development of Citation Matrix Table

The importance of matrices in the fields of business and economics has been recognized and extensively used for a long time.[46] Its introduction into the study of subject literature was heralded by Kessler[47] in his study: Some Statistical Properties of Citations in the Literature of Physics, in which he grouped together citations in twenty physics journals and from this created a to/from matrix of the percentage of cross-referencing between the journals. From this, a number of citation analysis studies of literature of subject fields have been conducted over the years using the input output citation matrix concept.

Using the same citation matrix concept, the one hundred fifty randomly selected journals were arranged alphabetically into the four defined research shells on a 6 x 6 foot square

board along a column A and row B (Appendix C). The Journal Citation Reports[48] of 1980 was used. From the cited/citing section of the report can be found, the cited journals with all the citing journals arranged under it according to ranking order of number of citations. With this type of arrangement, each cited journal along the column was taken, and the citing journals that belonged to any of the research shell categories were identified along the row B and the number of citations was recorded in the proper unit within the given research shell category. This was repeated for all the journals along the Column A. In this way the input/output citation matrix was developed.

The citation matrix table describes the flow of research information from one research shell into another. It is like the input/output matrix analysis developed by Leontief[49] in an industrial sector of economy. The use of this concept to analyze the flow of research information among the research shells shall be given in detail in the next chapter. The input-output citation analysis is considered the fundamental entity which contains the flow of research information describing the influence among units. It also contains the interdependencies between the citing research units and the cited research units. In the context of this study, the research units are the four defined research shells into which the biomedical science research journals have been classified. And operationally, the flow of research information denotes the total number (Q) of references made by

research journals in one research shell into another research shell. The general form of this citation matrix table can be represented by:

$$Q = \begin{bmatrix} C_{11} & C_{12} & C_{13} & C_{14} \\ C_{21} & C_{22} & C_{23} & C_{24} \\ C_{31} & C_{32} & C_{33} & C_{34} \\ C_{41} & C_{42} & C_{43} & C_{44} \end{bmatrix}$$

Such an input-output citation matrix table arrangement can give a vivid description of the nature of interactions among the journals within and across research shells. A member of a set which is referred to by a unit represents the number of unweighted citations issued by a given research shell and received by another research shell. Thus, a term C_{14} in the citation matrix table indicates the number of references research shell 1 gives to research shell 4.

To determine if there exists a significantly greater quantity of research information flowing from the direction of basic biomedical science research shell toward the direction of clinical practice shell than that flowing from the direction of clinical practice shell toward the direction of basic biomedical shell, the notion of "flow of research information" shall be given a simple mathematical expression:

Let $Q_i(\text{out})$ = total number of references made by a given research shell (S_i) to all research shells;

Q_i(in) = total number of references made to a given research shell (S_i) by all research shells; and

C_{ij} = the total number of unweighted citations from shell (S_i) to shell (S_j)

For example,

$$Q_1(\text{out}) = \sum_{j=1}^{4} C_{1j} = C_{11} + C_{12} + C_{13} + C_{14};$$

Q_1(out) describes the total number of citations from basic biomedical science research shell to other biomedical science research shells

$$Q_1(\text{in}) = \sum_{i=1}^{4} C_{11} = C_{11} + C_{21} + C_{31} + C_{41}$$

Q_1(in) describes the total number of citations from other biomedical science research shells to the basic biomedical science research shell.

These definitions were used as bases for constructing input-output citation analysis table involving the four research shells. The input-output citation analysis table constructed, was in turn used to compute an input-output citation coefficient matrix. The details and usefulness of this coefficient matrix are further discussed in chapter five.

If the ratio of Q_i(out)-to-Q_i(in) $\gg$ 1 then: The flow of research information from the shell S_i is significantly greater than that from the other research shells to shell S_i. For example, if i = 1, and

$\frac{Q_1(out)}{Q_1(in)} \gg 1$, then

the "effective direction" of flow of research information is from basic biomedical science research shell, that is research information originates from the basic research end of the continuum toward the other research shells.

The input-output citation coefficient matrix will be used to determine the degree of dependencies or interaction of one research shell on the other. And the table will enable one to examine the differences of self-citations among the research shells. If there are any significant differences, it would be possible to see how the number of self-citations reflect the research shell orientation.

The Effect of Increase in Size of Research Literature on the Flow of Research Information

To examine the effect of increase in size of research literature on the flow of citations across the four research shells, one hundred five originally classified research journals of the basic biomedical science research shell S_1 were divided and arranged into four journal groups following the general principle of Bradford's Law. This principle states that:

> If scientific journals are arranged in order of decreasing productivity of articles (journals) on a given subject, they may be divided into nucleus of periodicals more particularly devoted

> to the subject and several groups or zones containing the same number of articles as the nucleus, when the numbers of periodicals in the nucleus and succeeding zones will be as in $1:n:n^2$.[50]

The principle above has also been found to be applicable to authors.

In this study, the one hundred five journals were grouped such that the journals in each group had an approximately equal number of total citations. The number of source articles with their corresponding number of citations in the given year were collated using the source item package of the JCR of 1980.[51] The number of citations per journal and article were computed.

Using the input-output citation matrix table 6' x 6' board, already developed, the number of citations per journal in each of the four research shells from each group was computed. The total number of research articles, and citations for the one hundred five research journals was computed. The corresponding number of citations per article and per journal in each journal group were also computed. These were put in tabular form to see whether:

(i) there were differences in terms of the number of citations per article and journal in each group; and that

(ii) the number of citaticns per article and journal in each group actually decreased as one moved from the most productive journal group to the least productive journal groups.

The results of comparing the number of citations per journal in each group with that of the number of all the journals are discussed in detail in Chapter Five.

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CHAPTER FIVE

ANALYSIS OF DATA AND DISCUSSIONS OF RESULTS

Following the collection and coordination of the data based on the research shell structure, the analysis and discussions of the results of the study are organized according to the following aspects:

(i) "Research shell" classification scheme and how it is compared with Narin's "research level" classification scheme;

(ii) the patterns of flow of research information within and across research shells; and

(iii) the effect of the increase of the size of research literature on the flow of research information within and across research shells.

Research Shell Classification Scheme

One of the methodological difficulties encountered in this study was to give appropriate operational definitions to the four biomedical science research orientations. Such definitions not only provided the basis for testing the primary hypotheses and answering some principal questions, but in addition provided a validation of existence of "research shell" classification in the universe of scientific knowledge as perceived by the scientists themselves.

The question of whether there exists different biomedical science research orientations, which could be classified into research shells using biomedical science journals was examined by analyzing the questionnaires returned. The number of guidelines and questionnaires distributed and the number returned are illustrated in Table VI.

Table VI: Distribution and Return of Guidelines and Questionnaires to and from Biomedical Scientists and Practitioners.

	Guidelines and Questionnaires			Non-Usable		Percentage Returned	Percentage Usable
	Number Distributed	Number Returned	Number Usable	Number Unclassified	Number Disagreed		
Number of Experts	120	115	105	3	7	95%	87.5%
Number of Research Journals	350	350	314	14	22	100%	89.4%

Out of one hundred twenty guidelines and questionnaires distributed, one hundred fifteen (95.8%) were returned. One hundred twelve were duly completed and three not classified at all. Out of the returned completed guidelines, one hundred five (87.5%) were usable. From the guidelines dis-

tributed, there were three hundred fifty journals listed in all categories of biomedical science subfields. The one hundred five usable returned guidelines provided a classification for three hundred fourteen research journals (89.4%). Five of the guidelines were not returned and since these represented a small percentage of the total and also did not affect the overall number of research journals classified, effort was not made to follow up their returns. Ten of the returned guidelines were not usable. Three out of these which accounted for fourteen journals (4%) were returned with either explanations that they were not familiar with the listed journals and hence could not classify them or notes declining participation in the classification exercise. A closer examination of the fourteen journals not classified showed that many of the journal titles on the list represented foreign journals which probably were seldomly used by these experts. The remaining seven guidelines which accounted for twenty-two journals (6.3%) were discarded because of non-agreement of classification by at least two of the three experts in the given subfield.

The three hundred fourteen usable research journals come from forty biomedical science subfields. The usable classified research journals were collated and listed into the four defined research shells. Table VII illustrates the breakdown of the number of journals which were classified into each of the research shells by the experts.

Table VII: The Breakdown of the Number of Journals Classified Into Each Research Shell Category by Experts

Research Categories	The Number of Expert Agreements in the Classification of Journals in Each Research Category				
	3 ****	2 ***	1 **	0 *	Total
Basic Biomedical Science Research	93	12	5	2	112
Applied Biomedical Science Research	69	15	2	4	90
Clinical Research	56	17	5	6	84
Clinical Practice Research	43	9	10	2	64
Total	261	53			
	314		22	14	350

****The number of journals classified into one research category by three biomedical science experts.

***The number of journals classified into one research category by two biomedical science experts.

**The number of journals which were classified by three biomedical science experts into three research categories.

*Number of journals not classified at all.

The names of journals frequently listed and classified (not less than ten times) by the experts as valuable to their areas of specialization were found to be the same as those already on the guidelines. Journals frequently listed and classified by the experts included:

Science (twenty times)

Nature (fifty-one times)

Proceeding of the National Academy of Sciences U.S.A. (eighty-five times)

Journal of Lipids Research (twelve times)

The experts classified these research journals as basic biomedical science research journals.

In the pre-test stage of the development of the instrument (guideline), one of the experts raised the issue of overlaps in the defined categories. The expert observed that in the basic biomedical research shell, "the research journals actively reporting its research activities are easily identifiable as basic research journals, but the identification of those of other research shells is difficult as one moves away from the most basic science research orientations."[1] He agreed in his additional comment that, the universe of biomedical science literature can be classified into their research orientations.

Of the one hundred five experts who returned the usable guidelines, fifteen persons (12.5%) commented on the problem of "overlapping" characteristics of research journals in each of the research shells. Because of the overlapping characteristics of the type of research articles reported in the research journals, "to compartmentalize a biomedical science research journal into a water-tight shell is difficult although not impossible."[2] The experts recognized that every biomedical science research journal has a central objective directed toward a unique readership and biomedical research orientation. There was no objection raised against the defined research shell categories. They all seemed to agree that the universe of biomedical

science was roughly made up of conglomeration of basic research, applied research, technological research, and practice.

Another point raised was the unique characteristics of review journals of biomedical science. Review journals (to all who commented on this), belonged to a different class of their own. They stated that review journals performed the function of synthesizing the state of knowledge in a given field or specialization or a unit of field. Noting the unique characteristics of review journals, Bernstein and others in their article, The Hepatitis Knowledge Base,[3] stated:

> At its best, a review article is a transient miniature of the end product desired in an information transfer system; it is a high quality, analytic, organized, and compacted current synthesis of information in a given area. Drawing on personal knowledge and experience, the expert selects and presents to the readers a highly organized, concise and analytic summary. To bolster credibility of his or her views, the experts cite the highest quality and most relevant literature and because of usual constraints on page, space severely limits the numbers (and redundancy) of citations.

This unique characteristic of review journals in the universe of biomedical science literature could be understood more through the examination of stated aims of some of the biomedical science review journals. In introducing the Advances in Clinical Chemistry,[4] the editors in their preface stated:

> The central purpose of the publication is to provide the clinical chemists with reviews of "state-of-the-art" methodology, newer areas of medicine and physiology that affect clinical chemists and those areas related to the latest information relating chemistry to disease.

Forced by the deluge of research in immunochemistry and immunology, the experts in the field initiated an open-end treatise dealing with methodology. Thus, the aim of Methods in Immunology and Immurochemistry[5] is to open "colleagues'" notebooks and bring together, relevant and detailed procedures that are difficult to retrieve from the huge mass of biomedical science literature. As far back as 1932, the year of the first volume of Annual Review of Biochemistry,[6] the editor lamented:

> Most of us find ourselves buried amidst piles of unread papers. To keep abreast of the literature in biochemistry has become a herculean task. It is the exceptional individual who succeeds in reading an appreciable proportion of the papers outside the confines of his own restricted field of research. . . .

Stating the reason for starting the publication of the Annual Review in Biochemistry, he said,

> . . . for it is in the belief that critical surveys of the literature will minimize the tasks of constantly referring to original works that the ARB will present from year to year.[7]

From the analysis of the purpose and objectives of the origins of the review journals, the unique characteris-

tics become clear. The importance attached to review journals in the dissemination of research information by the experts lends support to the views expressed by some of them that review journals should be in a class of their own.

The acceptance of the defined research shells as a basis for the classification of research journals by the biomedical science experts gave an indication that the experts did understand the nature of the structure and classes of literature generated by them in a given research shell.

Comparison of "Research Level" and Research Shell Classification Schemes

Important to our understanding of the structure of biomedical science is the classification of its literature into different research orientations. The first attempt in this direction was made in the study of Narin and others[8] in which they used citation patterns of biomedical science journals to develop a "research level" classification scheme.

The extent to which the "research shell" classification scheme developed in the present study agrees with Narin's "research level" classification scheme is central and important to future development of valid and universally accepted classification system relevant to the understanding of the structure and the dynamics of scientific knowledge.

From Appendix D, the degree of agreement between the "Research Level" and the "Research Shell" Classification Schemes was prepared and is depicted in Table VIII. The two classification schemes were arranged in form of a matrix depicting the number of each journal classified by Narin along the vertical columns and that of experts along the horizontal row.

Table VIII: "Research Levels" and "Research Shells" Classification Comparative Table with the Percentage of Agreement

Number of Journals Classified Into Research Shells by Experts	Number of Journals Classified Into Research Levels by Narin				
	L_4	L_3	L_2	L_1	Total
S_1	102	2	1	-	105
S_2	6	69	9	-	84
S_3	-	3	51	19	73
S_4	-	6	8	38	52
Total	108	80	69	57	314
Percentage of Agreement With Narin	94.4%	86.3%	73.9%	66.7%	

Out of three hundred fifty journals originally selected for classification by experts, three hundred fourteen were classified into their defined research shell categories. These were compared with the same journals on the "research

levels" classification list developed by Narin in 1975. These three hundred and fourteen journals classified by the experts happened to have been classified by Narin also. Thus, the number of the research journals classified as basic biomedical science research by Narin, and which corresponded to that of basic biomedical science research shell 1 were compared and checked in the table as shown in Appendix D. The same procedure was repeated for each of the other research levels and research shells.

In Narin's "research levels" classification scheme, there were:

108 research journals classified as L_4;
80 research journals classified as L_3;
69 research journals classified as L_2; and
57 research journals classified as L_1.

In the "research shell" classification there were:

105 research journals classified as Shell 1;
84 research journals classified as Shell 2;
73 research journals classified as Shell 2;
52 research journals classified as Shell 4.

To determine the degree of agreement in Table VIII, the number of journals along the diagonal represented the degree of the number of agreement. Thus, one hundred two research journals classified as shell 1 (94.4%) corresponded with that of research level 4; there were sixty-nine for that of

shell 2 (86.3%); fifty-one for that of shell 3 (73.9%); and thirty-eight for that of shell 4 (66.67%).

This demonstrated the fact that more than 94% of the journals classified as basic biomedical science journals by the experts were classified as basic biomedical research journals by Narin; more than 86% of the clinical investigation journals of Narin were classified as applied biomedical science journals; more than 73% of the clinical mix journals of Narin were classified as clinical research journals; and more than 66% of the clinical practice journals of the present study were classified as clinical observation journals by Narin. These findings seem to reveal that there was a significant agreement (ranging from about 66% to about 94%) between the two classification schemes.

Why the percentage value of agreement is higher in the most basic research oriented shell than in any of the research shells; and that this percentage value of agreement decreases as one moves away from the basic research oriented end of the continuum toward the practice oriented research end, seem to underscore the cohesive nature of the basic biomedical science. It could also be conjectured that the experts, in the basic biomedical science research shell know their journals more than those of other research shells and so by implication are able to classify their journals more accurately.

Whether this percentage agreement between the two classification schemes is statistically significant is shown by finding the correlation coefficient of the two

variables and testing its statistical level of significance. If the two classification schemes have high intensity of association or have high positive correlation, then the value of Pearson-product-moment (r) cf the two variables will be high. Correlation is a measure of the degree to which variables vary together or a measure of the intensity of association.[9]

The sample correlation coefficient is mathematically defined by:

$$r = \frac{N(\Sigma XY) - (\Sigma X)(\Sigma Y)}{\sqrt{[N\Sigma X^2 - (\Sigma X)^2][N\Sigma Y^2 - (\Sigma Y)^2]}} \quad \cdots 5.0$$

where r is the Pearson-product moment coefficient of correlation or simply correlation coefficient. N is the number of journals classified; X is the number of ratings of individual journal in all research level categories and Y is the number of ratings of individual journal in all research shell categories.

For the sake of computing the correlation coefficient (r) relating the two classification schemes, each journal in each research level or shell category was given the rating as shown in Appendix D.

For example,

Narin's research level 4 = Expert's research shell 1 = 4

Narin's research level 3 = Expert's research shell 2 = 3

Narin's research level 2 = Expert's research shell 3 = 2

Narin's research level 1 = Expert's research shell 4 = 1

Table IX was constructed to reflect the ratings of each journal in each research shell.

Table IX: "Research Levels" and "Research Shells Comparative Table with Their Ratings

Number of Journals Rated (n)	Narin's Rating X	Expert's Rating Y	(X^2)	(Y^2)	n(XY)
102	4	4	1632	1632	1632
2	3	4	18	32	24
1	2	4	4	16	8
6	4	3	96	54	72
69	3	3	621	621	621
9	2	3	36	81	54
3	3	2	27	12	18
51	2	2	204	204	204
19	1	2	19	76	38
6	3	1	54	6	18
8	2	1	32	8	16
38	1	1	38	38	38

$N = 314; \sum X = 867; \sum Y = 870; \sum X^2 = 2781; \sum Y^2 = 2780;$
$\sum XY = 2737$

From Table IX, the total number of journals in each classification scheme = 314. Substituting the above values in equation (5.0)

$$r = \frac{314(2737) - (867)(870)}{\sqrt{(314(2781) - (867)^2}\ \sqrt{(314(2780) - 870)^2}}$$

$$r = \frac{859418 - 754290}{(\sqrt{873234 - 751689})(\sqrt{872920 - 756900})}$$

$$r = \frac{105128}{348.633 \times 340.617}$$

$$= 0.8852, \text{ a very high positive correlation.}$$

Testing the hypothesis that the correlation between the Narin's and expert's classification of research journals is statistically significant at probability P = 0.01 levels of significance,

H1: $r \geq r_{\alpha}$ where α = 0.01 is the level of significance

H0: $r \leq r_{\alpha}$.

Since the calculated value of ($r = 0.8852$, $P = 0.01$) is greater than the critical table value ($r = .174$, $P = 0.01$) for $N \geq 300$ then the correlation between the two classification schemes is statistically significant, and highly so.

The existence of a strong agreement between the two classification schemes seemed to suggest that the combination of and further modification of the two methods could lead to the development of a classification system different from the traditional systems which may be more relevant for the organization of scientific knowledge in general and biomedical science in particular. Since a substanstial

communication of research information within the universe of biomedical science is done through research journals, the development of a classification system based on the type of research published therein rather than the subject field may be more relevant to the organization of its literature.

The agreement between the two classification schemes also validates the use of citation methods to establish a useful classification scheme. However, more work is needed to be done to establish a universally accepted scheme based on citation analysis of referencing patterns in a given piece of research literature.

Interactions Between Each of the Biomedical Science Research Shells

During the process of the collection of data for this study, it was revealed that the number of citations flowing from one research shell to another depended on the relative distance between the research orientations. Thus the further apart two research shells were in their research orientations, the fewer the number of citations flowing between them. This observation led to the need to examine the degree of interactions between the research shells in terms of the number of citations made by one research shell from the others.

The input-output citation matrix displayed in Table X contains the information concerning the total flow of the number of citations from one research shell to the others. The rows of the input-output citation matrix table rep-

resent the number of citations and its corresponding percentages from one research shell to another and the columns represent the number of citations to one research shell from another. For example, C_{21} = 58822 is the number of citations from shell 1 into shell 2.

Table X: Input-Output Citation Matrix Table - Number of Citations in Cell and its Percentage of Total in Research Shell

Citations From	Citations To	Biomedical Science Research Shells			
		Shell 1 N = 50	Shell 2 N = 40	Shell 3 N = 35	Shell 4 N = 25
Shell 1	C	386904	58822	5613	321
	%	85.66%	13.02%	1.24%	0.07%
Shell 2	C	44703	110741	19662	4198
	%	24.93%	61.76%	10.97%	2.3%
Shell 3	C	4545	16147	79883	23421
	%	3.67%	13.02%	64.42%	18.89%
Shell 4	C	305	2630	18734	35264
	%	0.54%	4.62%	32.90%	61.95%

The number of citations flowing from shell 1 to other shells along the horizontal rows decreased from 386904 (85.66%) in shell 1 to only 321 (0.07%) in shell 4. This degree of interaction between the research shell 1 and shell 4 seemed to be incredibly small. The same diminishing characteristics of citations from one shell to others were observed in shells 2, 3, 4.

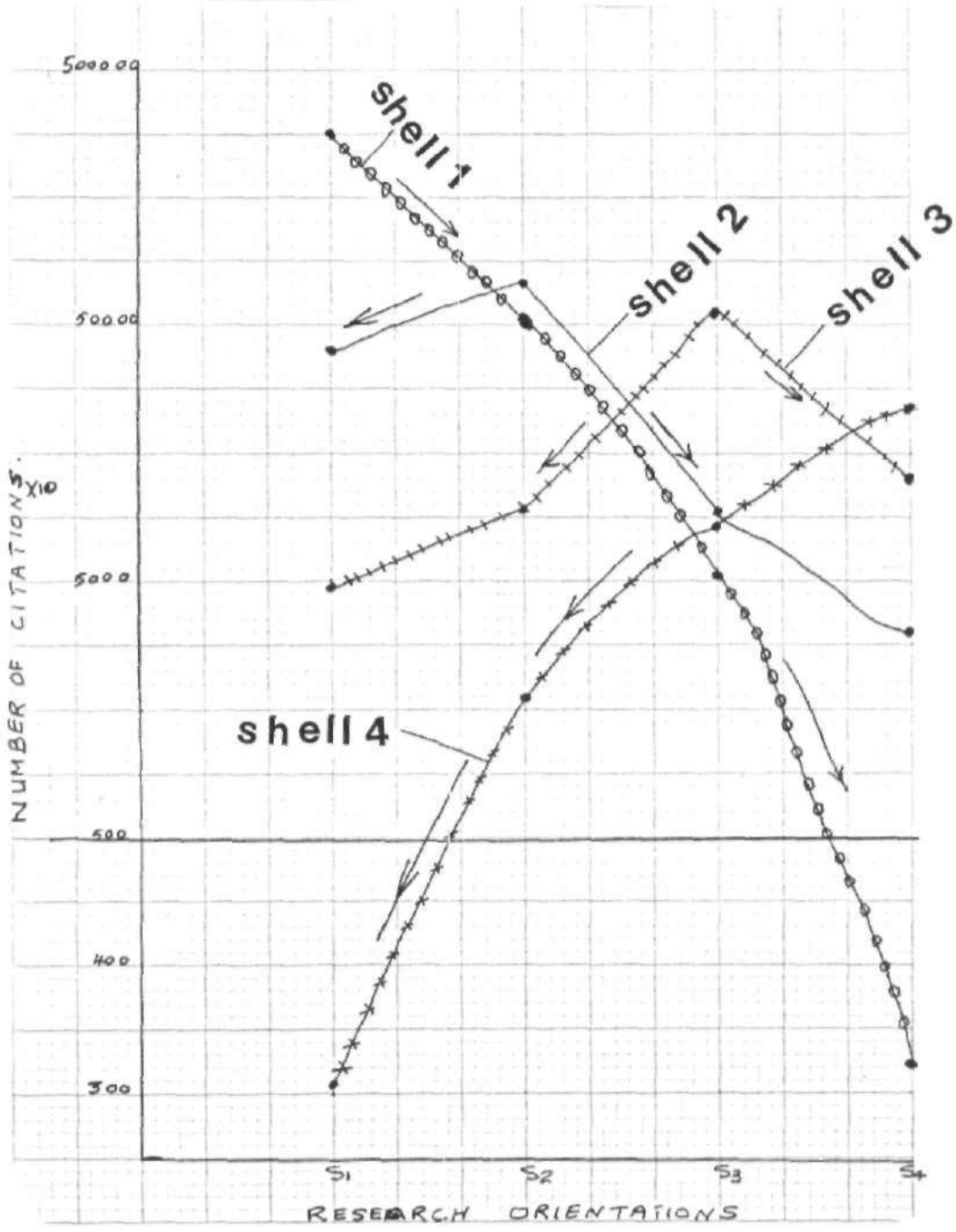
The diminishing number of citations from one shell to others within the universe of biomedical science is graphically illustrated in Figure 1. The number of citations from shell

1 to itself and to other remaining shells is designated by (00000); that from shell 2 by (_____); that from shell 3 by (++++); and that from shell 4 by (xxx).

These results show that there is very little interaction in terms of the flow of information in the form of citations from one given research shell to adjacent research shells. That there is seemingly little or no interaction between the basic biomedical science research and clinical practice research suggests that citation analysis alone may not completely describe the complex interaction between the various facets of the universe of scientific and technological research enterprise. It also seems to suggest the existence of a type of independence between the two ends of research orientations within the universe of biomedical science. It was hypothesized that a combination of citation analysis and other interactive study methods might be needed to study the complex question of interactions as they exist between different research orientations, and the apparent virtual independence observed to exist between the basic research shell and the other research shell of the universe of biomedical science.

Considering the total number of citations illustrated in Table XI the number of citations flowing from research shell 1 to all other shells was 451660. This represented about 2.52 times that of research shell 2 (179304); about 3.64 times that of research shell 3 (123996); and about 7.93 times that of research shell 4 (5694). In general

Figure 1: The Flow of the Number of Citations From One Shell to Other Shells Versus the Research Orientation.



therefore, the number of citations in basic biomedical science research shell was consistently greater than that of all the other number of citations in other shells. In the same way, the number of citations per journal and its percentage in each of the shells demonstrated the same differences between the research orientations.

Table XI: Percentage of Total Citations and Citations Per Journal in Each Research Shell

Number of Journals in Each Shell	Total Number of Citations to Each Shell	Number of Citations Per Journal in Each Shell	Percentage of Total %
Shell 1 N = 50	451660	9033	46.71
Shell 2 N = 40	179304	4483	23.18
Shell 3 N = 35	123996	3543	18.32
Shell 4 N - 25	56943	2278	11.78
Total	811903		100.0

These results seem to suggest that shell 1 (basic biomedical science) contains more highly cited research journals than any of the other biomedical science research shells. That is, by implication, this research shell generates greater number of citable research information which are valuable for research activities within the universe of

biomedical science. The decreasing characteristics observed as the research orientation moves from the most basic research oriented end of the continuum to the most practice research oriented end, supports the notion of existence of differences in research activities in the different research shells.

Looking at the patterns of the total number of citations per journal in each research shell, the intensity of the number of citations per journal decreased from 9033 in shell 1 to 4483 in shell 2; to 3543 in shell 3; and to 2278 in shell 4. These suggest that research activities as demonstrated in the number of citations per journal decrease as one moves from the most basic research oriented end of the continuum to the most practice research oriented end. It can therefore be conjectured at this stage that the research workers within the basic biomedical science research shell undertake more research works and hence generate and utilize more research information than in any of the other research shells. It can also be suggested that, since more utilizable research information is generated in this research shell, it contributes more directly or indirectly to the general development of research in biomedical science and by implication to the practice of medicine as a whole.

Further, Table XII illustrates the diminishing degree of interactions in terms of number of citations per journal made in a given research shell. The number of citations per journal decreased from 7738 (82.48%) in shell 1 to only 13 (0.14%) in shell 4. The number of citations per journal in

the three other shells 2, 3, 4 demonstrates the same diminishing pattern according to the "relative distance" between two research orientations.

The results of this study demonstrate the existence of different research shells within the universe of biomedical science. It revealed that along the continuum of the universe of biomedical science, basic biomedical science research shell has the greatest number of citations flowing from it to all others (451660); and while others taking in order of their relative positions in the continuum were 179304, 123996, and 56943 respectively. The number of citations per journal and their corresponding percentages of citations also supported the notion of research shell orientations of biomedical science.

The results also indicate that the nearer a research orientation is to another, the greater the interaction in terms of the number of mutual citations. This could be attributed to the fact that two adjacent research shells are likely to be nearer in both their professional and research activities and by implication in their social relationship. If this is the case in general, then it could be explained that the nearer the research shells are in orientation, the easier it is for them to be able to assimilate the research literature generated in each research shell.

Considering the number of citations in both the rows and the columns of the input-out citation matrix table, there were observable numbers of citations from and into other

Table XII: Degree of Interactions Between One Research Shell and Others in Terms of the Number of Citations Made Per Journal From Each of the Research Shells.

	Citations Per Journal	
	C	D = %
$S_1 \rightarrow S_1$	7738	82.48
$S_1 \rightarrow S_2$	1471	15.68
$S_1 \rightarrow S_3$	160	1.70
$S_1 \rightarrow S_4$	13	0.14
Total	9382	100.00
$S_2 \rightarrow S_1$	894	20.35
$S_2 \rightarrow S_2$	2769	63.03
$S_2 \rightarrow S_3$	562	12.80
$S_2 \rightarrow S_4$	168	3.82
Total	4393	100.00
$S_3 \rightarrow S_1$	91	2.45
$S_3 \rightarrow S_2$	404	10.88
$S_3 \rightarrow S_3$	2282	61.44
$S_3 \rightarrow S_4$	937	21.23
Total	3714	100.00
$S_4 \rightarrow S_1$	6	.30
$S_4 \rightarrow S_2$	66	3.27
$S_4 \rightarrow S_3$	535	26.51
$S_4 \rightarrow S_4$	1411	69.92
Total	2018	100.00

C = The number of citations flowing from one shell to the others divided by the number of research Journals in the given cell of the shell.

D = The corresponding percentage of the total of citations per journal within the shell.

research shells. Although such observable number of citations decreased remarkably as one research shell moved away from another in their research orientations, there existed a bi-directional exchange of citations between the research shells. This bi-directional exchange of citations led to the need of determining whether there existed an "effective direction" of the flow of citations within the universe of biomedical science. To do this, an input-output analysis method[10] developed by Leontief in 1936 to examine the dynamics and interdependencies of the various sectors of the economy was adapted and used to analyze the input-output citation matrix of the study.

One of the most fundamental problems in understanding the generation and utilization of research information is that of determining the relationship between the generating and utilizing characteristics of research information in the universe of scientific literature. Such understanding is important to research information management and retrieval practices. In adapting the input-output analysis economic model of Leontief, it is hypothesized that such model can be applied to study the citing and cited characteristics of research information and thus determine the pattern of interdependencies between the various research orientations and the flow of research information among them.

It is a common practice among most research workers, that the process of starting any research project and which leads to generation of further research literature always

involves the use of existing research literature. Thus, the use of the concept of Leontief input-output analysis model is pertinent to the issue.

The necessary elements involved in the process of Leontief's input-output analysis model are: (1) specified national economy; (2) the producing and consuming sectors of the economy; and (3) the interdependencies of the producing and consuming sectors and the flow of goods produced in the system. This input output method is an adaptation of the theory of general equilibrium to the empirical study of the quantitative interdependence between interrelated economic activities. It was originally developed by Leontief to analyze and to measure the connections between the various producing and consuming sectors within a national economy, but has also been applied, on the one hand, in the study of smaller economic systems such as a metropolitan area or even of a large integrated individual enterprise and, on the other hand, to the analysis of international economic relationships.

In all instances, the methods of approach are basically the same: the interdependence between the individual sectors of the given system is described by a set of linear equations; its specific structural characteristics are thus reflected in the numerical magnitude of the coefficients of the equations. These coefficients are determined empirically; in the analysis of the structural characteristics of an entire national economy they are derived from a statistical input-output table. The entire process therefore involves

the number of goods produced by a given number of processes which use these goods as input in the system. For simplicity an assumption is made that each process produces just one of the goods and that each good is the result of some processes. The term "good" is used in a wide sense to include almost anything of use or interest to man.

It is to be noted that the model described above is an idealization of the real situation in which the complex processes are reduced to its essential properties.

In general, this input-output can be characterized as one in which (n) goods produced by (n) processes use these goods as input. How this can be applied to study the relationship of the generation and utilization of research literature in the universe of scientific knowledge, demands giving approximate appropriate interpretations to the economic elements in terms of the elements in research literature.

New research literature cannot always be generated without going through the process of using the existing research literature (goods) as input. In doing this, the generator of the new research literature always makes references to the existing research literature. In the same way, the existing research literature provides sources of references to the new research projects. This process results in an input-output characteristic.

Table XIII interprets the economic terms into approximate equivalent research literature terms.

Table XIII: Elements of the Dynamics and Interdependencies of Producing and Consuming Sectors of Economic System Interpreted in Terms of Citation Flows Among Research Shells

Elements of Input-output Process	Elements Interpreted in Terms of	
	Interdependencies of Producing and Consuming Sectors of an Economy	Relationship Between Generation and Utilization of Research Literature
Existence of an Economic System	National Economy	Universe of Research Literature
Producing Sector	Goods produced by given number of processes and which are also used as input	Ideas, facts, findings, theories and methods generated by the process of making references to the existing literature. These are also sources of reference for future research projects (input).
Consuming sector	Products and services provided as a result of goods produced.	Sources of references provided for ongoing research project as a result of research literature generated
Interdependencies of producing and consuming sectors of an economy	(a) Amount of products (goods) produced by industry	Number of ideas, facts, methods, and theories made available by a given research shell
	(b) Amount of products demanded by industry	Number of ideas, facts, theories and methods needed by a given research shell. One of the observable by-products of a research shell is the amount of research literature generated by it. Its research demands are reflected in the number of citations made to/from the given research shell.

Table XIII (continued)

	(c) Amount of products (goods) demanded after product requirement (for exports, industries not considered in the model, etc.).	References used by other information elements in addition to the one used by the given research shell. That is, the information elements such as (journals, author articles, etc.) referred to by the other research shells.

Although input-output analysis model as developed to study the interdependencies and flow of goods in an economic system can be considered as a special case of a general process applicable to input-output characteristics of research literature in form of references made from one research shell to another, there is an important difference to be noted. Input-output characteristics of an economic system is an information that measures the relationship between the production and consumption of goods in the system. Without a viable need for given goods, such goods are not produced. Thus, there is production of goods based on the demand. The nature of the needs for research literature to carry out research projects cannot easily be interpreted in the same way as in economic setting. This difference, however, does not pertain to the general structure of the process but only to external factors. In one case, the central desire is to boost the growth of the economy, while in the other, the growth of research literature arising from the use of past

research information resources cannot easily be measured and interpreted to be the growth of research shell, though it is implicitly implied.

In developing and using the method to examine the interflow and interdependencies of producing and consuming sectors of an economic system, the following general mathematical argument is formulated:

Let X_i denote the amount of product i produced by industry i; S_{ij} denotes the amount of product i that is demanded by industry j; and d_i denotes the amount of product (i) that is demanded after production needs are met (for export, industries not considered in the model etc.). These quantities are related according to the system of equations given by (5.1).

$$\begin{aligned} X_1 &= S_{11} + S_{12} + \text{----} S_{1n} + d_1 \\ X_2 &= S_{21} + S_{22} + \text{----} S_{2n} + d_2 \\ &\vdots \\ X_n &= S_{n1} + S_{n2} + \text{----} S_{nn} + d_n \end{aligned} \qquad (5.1)$$

Thus, if X is denoted by $(X_i)_n$, that is

$$X = (S_i)_{nx1} = \begin{bmatrix} X_1 \\ X_2 \\ \vdots \\ X_n \end{bmatrix}$$ usually called column matrix or column vector,

$$S = \left[\sum_{j=1}^{n} S_{ij}\right]_{nxn} = \begin{bmatrix} S_{11} & S_{12} & \text{----} & S_{1n} \\ S_{21} & S_{22} & \text{----} & S_{2n} \\ \vdots & \vdots & & \vdots \\ S_{n1} & S_{n2} & \text{----} & S_{nn} \end{bmatrix}$$ is called n columns by n rows matrix or nxn square matrix;

$$D = (di)_n = \begin{bmatrix} d_1 \\ d_2 \\ \vdots \\ d_n \end{bmatrix} \quad \text{column vector;}$$

Then the system of equation in (5.1) can be represented in their matrix form:

$$\begin{bmatrix} X_{11} \\ X_{21} \\ \vdots \\ X_{n1} \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} & \text{----} & S_{n1} \\ S_{21} & S_{22} & \text{----} & S_{n2} \\ \vdots & & & \\ S_{n1} & S_{n2} & & S_{nn} \end{bmatrix} + \begin{bmatrix} d_1 \\ d_2 \\ \vdots \\ d_n \end{bmatrix} \qquad (5.1a)$$

$$X = S + D \qquad (5.2)$$

The fundamental assumption associated with this model is that <u>the amount of product i demanded by industry j is directly proportional to the amount of product j produced</u>,[11] that is $S_{ij} = a_{ij}x_j$ where a_{ij} is the constant of production in the economic term and is called the technical coefficient of production. In other words, it is the amount of input a_{ij} units of the jth product (j=1, 2, ---- n) needed to produce a unit of output of the ith product assuming ith process (i=1, 2, ---- n) operates at a unit intensity. The equation can be written as: $X = AX + D$ (5.3), where X is defined as the intensity vector of the economy, that is, the total amount of products j needed as input and it is given as

$$\sum_{i=1}^{n} a_{ij}x_i$$

(i = 1, 2, ---- n)
(j = 1, 2, ---- n)

and so the total input of the economy can be expressed by the vector AX. D called the demand vector is defined as the total amount of products demanded after production needs are met. That is, the amount of products i demanded for exports and by industries not considered in the model.

Other assumptions which followed from the principal one include:

$$d_i \geqslant 0,\ a_{ij} \geqslant 0$$

and these indicate that surplus will always be depleted and that each industry produces one product. From this assumption, it follows that an intensity vector $X \geqslant 0$ can be determined such that $\boxed{(I - A)X = D}$ 5.4.

The acceptance of the fundamental assumption that the amount of product i demanded by industry j is directly proportional to the amount of product j produced can be applied to citing/cited characteristics of research shells (that is the number of references i used by research shell j is directly proportional to the number of references j produced) implies that each research shell is a sector generating unique research information which is needed by other research shells.

The mathematical arguments of the input-output analysis economic model can thus be translated into input-output analysis of citation in research shells. The universe of biomedical science literature is classified into four research shells (designated as cited research shells S_i (i = 1, 2, ---- 4) and citing research shells S_j (j = 1, 2, ---- 4). The

intensity vector (Q) like the economic intensity vector X is defined as the total number of references needed as input and can be expressed as:

$$\sum_{i=1}^{n} C_{ij}Q_i \qquad (i = 1, 2, \text{---- } 4)$$
$$(i = 1, 2, \text{---- } 4)$$

and so the total number of citations can be expressed by the vector (CQ). C_{ij} becomes the constant of proportionality of references made and thus it is called citation coefficient of generation of research literature.

D called the demand vector is defined as the total amount of references used by other information elements (such as: journals, authors, research orientations of other fields) in addition to the one used by the given research shells.

Rewriting equation (5.1a) into the present general form: substituting X_i by Q_i; X by Q; and S_{ij} by F_{ij}

$$Q = \left(\sum_{i=1}^{n} q_i\right)_{nx1} = \left(\sum_{j=1}^{n} F_{ij}\right)_{nxn} + (d_i)_{nx1}$$

where $F_{ij} = C_{ij}q_i$ and nx1 = vector matrix; nxn = square matrix (n = 1, 2 ---- 4)

$$Q = \begin{bmatrix} q_1 \\ q_2 \\ q_3 \\ q_4 \end{bmatrix} = \begin{bmatrix} C_{11}q_1 + C_{12}q_1 + C_{13}q_1 + C_{14}q_1 + d_1 \\ C_{12}q_2 + C_{22}q_2 + C_{23}q_2 + C_{24}q_2 + d_2 \\ C_{13}q_3 + C_{23}q_3 + C_{33}q_3 + C_{34}q_3 + d_3 \\ C_{14}q_4 + C_{24}q_4 + C_{34}q_4 + C_{44}q_4 + d_4 \end{bmatrix} \qquad 5.4$$

Thus

$$Q = CQ + D \qquad (5.5)$$

$$(I-C)Q = D \qquad (5.6)$$

Q 0 is the citation intensity vector

While the validity of the application of this method and its subsequent interpretation of the economic terms into research information terms has not been established, the fact that there always exists the giving and receiving of citations to research information among the various sectors of research communities, makes such interpretation plausible. Its value for the study of the pattern of flow of citations among the research shells derives from the analogy between the producing sectors of the economy and cited sectors of research shells, and between the consuming sectors of the economy and the citing sectors of research shells.

Using the 6' by 6' citation matrix analysis board, the input-output citation was constructed. The pattern of the number of citations generated and utilized by each of the biomedical science research shells is illustrated by Table XIV. The tables display outputs of citation from each research shell in corresponding horizontal row, inputs to each research shell in vertical column. The entries in column five which is designated by D is the difference between the number of citations generated within a given research shell and those utilized by the research shells. The entries in column six called Q is the total output of citations in a given research shell.

Table XIV: Input-Output Citation Analysis Table

Number of Citations in Cited Shells	Number of Citations in Citing Shell				(O-C)/D Number of Citations Not Used by the Research Shells	(O) Total Citations Output
	Shell 1	Shell 2	Shell 3	Shell 4		
Shell 1	386904	58822	5613	321	501349	953009
Shell 2	44703	110741	19662	4198	271460	450764
Shell 3	4545	16147	79883	23421	252414	386410
Shell 4	305	2630	18734	35274	117066	174009

Notation: Shell 1 = Basic Biomedical Science Research

Shell 2 = Applied Biomedical Science Research

Shell 3 = Clinical Research

Shell 4 = Clinical Practice Research

The input-output coefficient matrix was constructed from the assumption that

$$F_{ij} = C_{ij}q_i$$

Thus, the number of citations of the cited research shell (S_i) absorbed by citing research shell (S_j) per unit of its total output is mathematically expressed by

$$\frac{F_{ij}}{q_i} = C_{ij}$$

$C = \frac{F}{Q}$ where $C = \sum_{j=1}^{4} (C_{ij})_{4x4}$; $F = \sum_{j=1}^{4} (C_{ij}q_i)_{4x4}$ and

$Q = (q_i)_{4x1}$. The above expression can be written

$$C = \left(\sum_{i=1}^{4} \frac{C_{ij}q_i)_{4x4}}{(q_i)_{4x1}}\right. \qquad 5.7$$

From equation (5.7) and information in Table XIV, Table XV was constructed:

Table XV: Input-output Coefficient Citation Matrix

$$C = \begin{bmatrix} 0.4060 & 0.1305 & 0.0145 & 0.0018 \\ 0.0469 & 0.2457 & 0.0509 & 0.0241 \\ 0.0048 & 0.0358 & 0.2067 & 0.1346 \\ 0.0003 & 0.0058 & 0.0485 & 0.2027 \end{bmatrix}$$

From equation (5.6)

$\boxed{Q(I-C) = D}$ where I is mathematically defined and known as an identity matrix and in this case a fourth order identity

matrix. This has remained the equation of the input-output analysis. The above equation implies that given the input-output coefficient citation matrix (C) of the universe of biomedical science which is made up of four research shells and with the number of citations generated by a given research shell it is possible:

(i) to show the "effective direction" of the flow of the number of citations in the universe of biomedical science and thus be able to examine the hypothesis that the output number of citations is greater than the input number of citations;

(ii) to examine the degree of dependence of one research shell on others;

(iii) to show that the more research oriented a given research shell is, the higher the values of the ratios of citations from-to-citations to; and

(iv) to determine the change in the number of citations flowing into each research shell as the number of citations generated by a given research shell is altered.

(I) being the Identity matrix, and (C) the input-output coefficient citation matrix, let M = (I-C), then

$$M = (I - C) = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} - \begin{bmatrix} 0.4060 & 0.1305 & 0.0145 & 0.0018 \\ 0.0469 & 0.2457 & 0.0509 & 0.0241 \\ 0.0048 & 0.0358 & 0.2067 & 0.1346 \\ 0.0003 & 0.0058 & 0.0485 & 0.2027 \end{bmatrix}$$

$$M = \begin{bmatrix} -0.5940 & -0.1305 & -0.0145 & -0.0018 \\ -0.0469 & 0.7543 & -0.0509 & -0.0241 \\ -0.0048 & -0.0358 & 0.7933 & -0.1346 \\ -0.0003 & -0.0058 & -0.0485 & 0.7973 \end{bmatrix} \quad (5.8)$$

Considering the given input-output analysis model, $D \gg 0$ has been specified, it is possible to solve the matrix equation (5.6) for Q. For emphasis, Q is the citation intensity vector. If (I-C) exists, then $Q = (I-C)^{-1}D$. This gives the intensity Q at which the cited/citing system must operate to produce references needed by other information elements which were not included in the research shell. In other words, Q is defined as the total number of references needed as input to give rise to a number of citations.

Therefore from (5.8)

$Q = (M)^{-1}D$

$$M^{-1*} = \begin{bmatrix} 1.7075 & 0.2980 & 0.0517 & 0.0216 \\ 0.1073 & 1.349 & 0.0920 & 0.0565 \\ 0.0156 & 0.0650 & 1.2783 & 0.2178 \\ 0.0024 & 0.0139 & 0.0784 & 1.2679 \end{bmatrix}$$

---

*The above inverse matrix M^{-1} was computed using SMISSIS (Symbolic Matrix Interpretive System and Statistical Interpretive System) a computer program developed in California in 1974.[12] See the computer printout of the Inverse Matrix M Table XVI.

Table XVI · Computer Print-Out of Inverse Matrix M

```
 DNCWOQL. 83/09/12.I.U.CYBER 172 MMF SYSTEM.

17.27.08.JOB READ AT  17.27.07. 83/09/12.
17.27.08.DNO
17.27.08.ACCOUNT,5073,.
17.27.08.ATTACH(SMISSIS/UN=7124A)
17.27.09.SMISSIS.
17.27.14.EXIT
17.27.14.CP          28     SEC.
17.27.14.CP          1.671  SEC.
17.27.14.CM          0.009  KWH.
17.27.14.MS          0.371  KPR.
17.27.14.CM          0.035  MWS.
17.27.14.BU          0.050


START
LOAD   M       (4F6.0 )
    4 ROWS,      4 COLUMNS
PRINT  M

                1                2                3                4
    1    .5940000        -.1305000       -.1450000E-01 -.1800000E-02
    2   -.4690000E-01     .7543000       -.5090000E-01 -.2410000E-01
    3   -.4800000E-02 -.3580000E-01      .7933000      -.1346000
    4   -.3000000E-03 -.5800000E-02 -.4850000E-01       .7973000

INVERS M
DETERMINANT =    .27556936
PRINT  M

                1                2                3                4
    1    1.707461        .2980218        .5165039E-01  .2158271E-01
    2    .1072913        1.349095        .9197945E-01  .5654929E-01
    3    .1557531E-01    .6504060E-01    1.278331      .2178087
    4    .2370413E-02    .1388264E-01    .7844982E-01  1.267902

STOP

17.27.17.DNCWOQL-WC  KRONOS 2.1-(172)
17.27.23.LP44        0.066 KLN. WCC
```

Table XVII. Citation Intensity Table

$$Q = \begin{bmatrix} 1.7075 & 0.2980 & 0.0517 & 0.0216 \\ 0.1073 & 1.3491 & 0.0920 & 0.0565 \\ 0.0156 & 0.0650 & 1.2783 & 0.2178 \\ 0.0024 & 0.0139 & 0.0784 & 1.2679 \end{bmatrix} \quad \begin{bmatrix} 501349 \\ 271460 \\ 262414 \\ 117066 \end{bmatrix}$$

Q being the citation intensity, derived by multiplying each element in a row by each element in a column vector, represented the total number of citations flowing from one research shell to the other. And the answers derived by multiplying each element in a column by each element in column vector, represented the total number of citations flowing into each research shell from every other.

From the above, the flow of research information in terms of the total number of citations from one research shell to the others was computed accordingly. The outflow and inflow of citations were determined without considering the diagonal elements of the inverse matrix since the values obtained from these represents the self-citations.

1. The number of citations from research shell 1 to research shells 2, 3, 4 (outflow of citations),

$$Q_1(\text{out})_{2,3,4} = 501349\ (0.2980 + 0.0517 + 0.0216)$$

$$= 149402.00 + 25919.74 + 10829.14$$

$$= 186150.88$$

The number of citations to research shell 1 from research shells 2, 3, 4 (inflow of citations)

$$Q_1(in)_{2,3,4} = 271460\ (0.1073 + 262414\ (0.0156) + 1.7066\ (0.0024)$$

$$= 29127.66 + 4093.66 + 280.96$$

$$= 33502.28$$

$$\frac{Q_1(out)}{Q_1(in)} = \frac{186150.88}{33502.28}$$

$$= 5.56$$

The outflow of citations from shell 1 (basic biomedical science) to all outer research shells was about 5.56 times greater than the inflow of citations from all outer research shells to inner research shell 1.

2. The number of citations from research shell 2 to research shells 3, 4 (outflow)

$$Q_2(out)_{3,4} = 271460\ (0.0920 + 0.0565)$$

$$= 24974.32 + 15337.49$$

$$= 40311.81$$

$$Q_2(in)_{3,4} = 262414\ (0.0650 + 117066\ (0.0139)$$

$$= 17056.91 + 1627.22$$

$$= 18684.13$$

$$\frac{Q_2(out)}{Q_2(in)} = \frac{40311.81}{18684.13}$$

$$= 2.16$$

The outflow of citations from shell 2 (applied biomedical science) to shells 3, 4 was about 2.16 times greater than the inflow of citations from shells 3, 4 to shell 2.

3. The number of citations from research shell 3 to research shell 4 (outflow).

$$Q_3(out)_4 = 262414\ (0.2178)$$
$$= 57153.77$$

$$Q_3(in)_4 = 117066\ (0.0784)$$
$$= 9177.97$$

$$\frac{Q_3(out)}{Q_3(in)} = \frac{57153.77}{9177.97}$$

$$= 6.23$$

The outflow of citations from shell 3 (clinical research) to shell 4 was about 6.23 times greater than the inflow of citations from shell 4 to shell 3. In the above three cases, there were number of citations flowing from the applied biomedical science, clinical research and clinical practice research shells (33502.28) into the basic biomedical science research shell; and from the basic biomedical science research shell to these other outer research shells (186150.88). The same results were found when each of the other research shells were examined with respect to other outer research shells. This pattern of flow of citations within the universe of biomedical science demonstrates the bi-directional flow characteristics of research information. The findings that the flow of the number of citations from the inner research shells (taking them in turn) to the outer research shells was always greater than those flowing from outer research

shells to inner research shells seemed to support the hypothesis that the quantity of research information in the form of the number of references made from the basic biomedical science research shell by any of the outer biomedical science research shells is significantly greater than that of outer biomedical science research shells to the basic biomedical science research shell. This seemed to also demonstrate the existence of "effective direction" of research information to be from the basic biomedical science research orientation to the clinical practice research orientation. These findings suggest that the outer research shells of the universe of biomedical science depended more (five times) on research information from the innermost research shell than the inner research shell on any of the outer research shells. The same findings were identified when each research shell was examined with respect to other outer research shells.

These results seemed to support the notion that the universe of the literature of biomedical science could be defined as consisting of four different research shells at one end of which lies the basic biomedical science research shell and on the other end the clinical practice research shell. The applied biomedical science and clinical research shells existed between the two ends of the universe of biomedical science. The findings also demonstrated the differences in research orientations. The nearer in research orientation a given research shell was to basic biomedical science orientation, the greater the flow of citations between basic

biomedical science research and that orientation. Thus, the applied biomedical science research shell which is next in research orientation to basic biomedical science research shell has greater citation interaction with it than that of clinical practice research shell which is considered to be at the most practice end of the universe of biomedical science.

Considering the differences in terms of self-citations, Table XVIII illustrates the degree of the differences between the four research shells.

Table XVIII: Self-Citation in Each Research Shell

Research Shell Category		Total Self-Citation in Each Research Shell	Total Self-Citation Per Journal in Each Research Shell	
Basic biomedical science	S_1	856,053.4	17121.1	(A)
Applied biomedical science	S_2	366,226.7	9155.7	(B)
Clinical research	S_3	335,443.8	9584.1	(C)
Clinical practice	S_4	148,428.0	5937.1	(D)

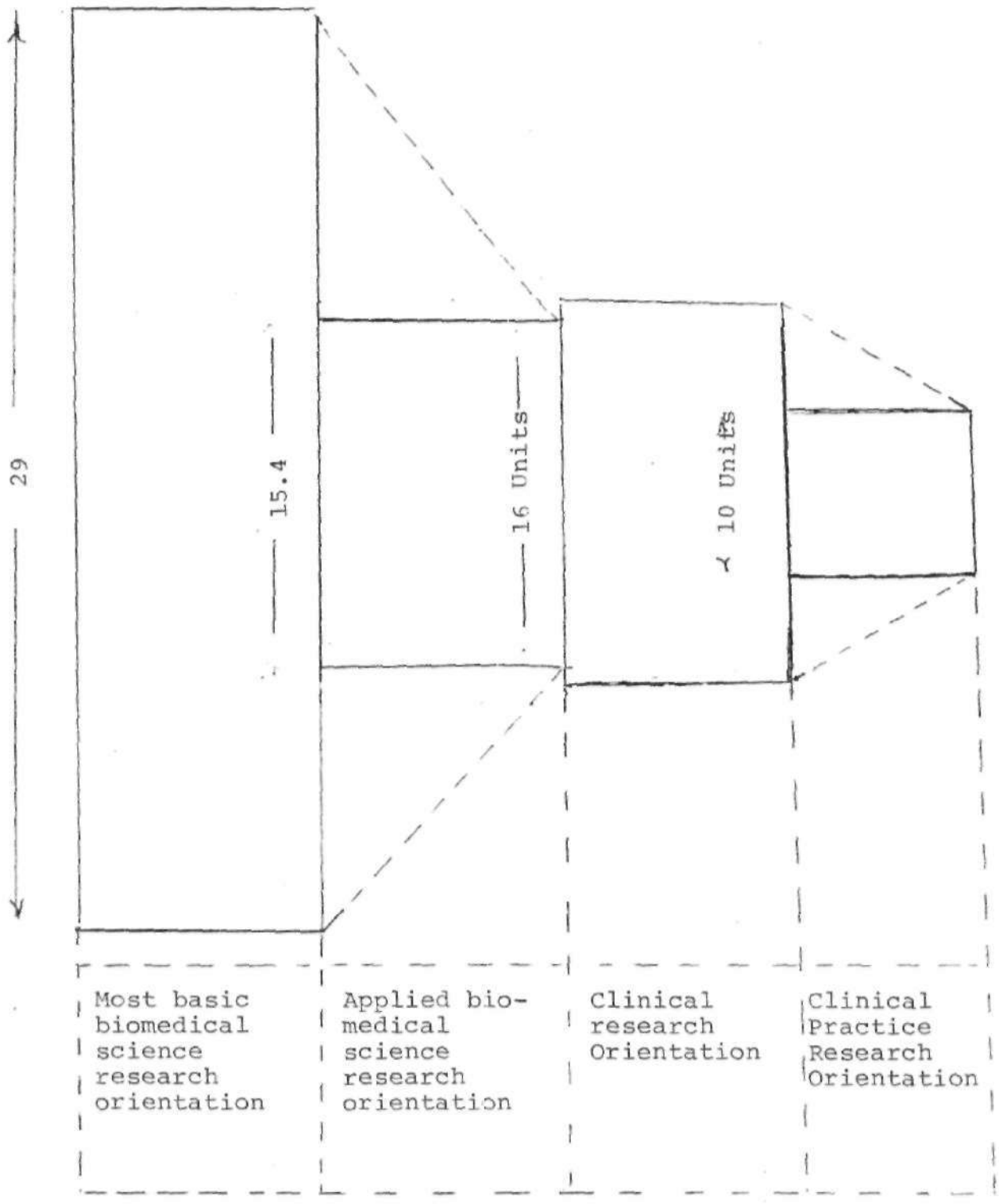
The value of A:B:C:D = 2.88:1.54:1.61:1

Multiply by 10 = 28.8:15.4:16.1:10.0

Approximately = 29:15:16:10

These findings which are illustrated in Figure 2, showed the fact that the most basic oriented research shell cited

Figure 2: Differences Between the Various Research Shells Within Biomedical Science as Demonstrated by the Self-Citation.



more of itself (17121.1) than any of the other research shells and the rate of self-citations decreased as the research orientations moved from basic research center to practice research. The rate of self-citations for applied biomedical science research shell (9155.7) and that of clinical research shell 9584.1 are approximately equal. The rate of self-citations in clinical practice research was the smallest (5937.1). The approximate equal number of self-citations in the two middle research shells seem to suggest that both of these research shells have the same amount of research activities. This can be conjectured to mean that both have nearly the same research goals which include the application of the existing body of knowledge in the universe of biomedical science to the solution of medical problems.

To determine the degree of dependency* of one research shell on another, the number of citations from shell 1 to each of the other shells and those from each of the other shells to shell 1 were computed using citation intensity Table XVII. The same computation was repeated for shells 2, 3, and 4. Thus, a table of citations outflow and inflow was developed as depicted in Table XIX.

Table XIX represents the pattern of flow of citations outward and inward taking one research shell with respect to all others. The ratios of the outflow of citations to inflow of citations denote the dependency relationship of

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*Dependency in the context of this study is defined as the number of times citations out is more than citations in, when comparing the cited/citing patterns of each research shell. Thus, it is the ratios of citations out: citations in.

Table XIX: The Pattern of Flow of Citations From One Research Shell to Another and Their Dependency Relationship.

	Number of Citations Flowing Out	Number of Citations Flowing in	Dependency Ratio
Shell	X	Y	$\frac{X}{Y}$
S_1	$S_1 \rightarrow S_1$ = 856053	$S_1 \leftarrow S_1$ = 856053	1**
	$S_1 \rightarrow S_2$ = 145391	$S_2 \rightarrow S_1$ = 29128	4.99
	$S_1 \rightarrow S_3$ = 25920	$S_3 \rightarrow S_1$ = 4094	6.33
	$S_1 \rightarrow S_4$ = 10829	$S_4 \rightarrow S_1$ = 281	38.53
S_2	$S_2 \rightarrow S_2$ = 366200	$S_2 \leftarrow S_2$ = 366200	1**
	$S_2 \rightarrow S_3$ = 24974	$S_3 \rightarrow S_2$ = 17057	1.46
	$S_2 \rightarrow S_4$ = 15337	$S_4 \rightarrow S_2$ = 1627	9.43
	$S_2 \rightarrow S_1$ = 29128	$S_1 \rightarrow S_2$ = 145381	*
S_3	$S_3 \rightarrow S_3$ = 335444	$S_3 \leftarrow S_3$ = 335444	1**
	$S_3 \rightarrow S_4$ = 57154	$S_4 \rightarrow S_3$ = 9178	6.23
	$S_3 \rightarrow S_2$ = 17057	$S_2 \rightarrow S_3$ = 24974	*
	$S_3 \rightarrow S_1$ = 4094	$S_1 \rightarrow S_3$ = 25920	*
S_4	$S_4 \rightarrow S_1$ = 281	$S_1 \rightarrow S_4$ = 10829	*
	$S_4 \rightarrow S_2$ = 1627	$S_2 \rightarrow S_4$ = 15337	*
	$S_4 \rightarrow S_3$ = 9178	$S_3 \rightarrow S_4$ = 57154	*
	$S_4 \rightarrow S_4$ = 148428	$S_4 \leftarrow S_4$ 148428	1**

** Self-Dependency is not considered in the discussion that follows.
* The dependency ratio are not determined in the reverse direction since these are not relevant in the discussion.

one shell over the other. The results seemed to suggest that as the "relative position" of a defined research shell moved away from the most basic biomedical science research shell to the most clinical practice research shell:

(a) The number of citations flowing out decreased. In shell 1 it decreased from 856053 to 10829; in Shell 2 it decreased from 366200 to 15337; in shell 3 it decreased from 335444 to 57154; in shell 4 it has no outward flow of citations because shell 4 is the last research shell in the continuum.

These findings demonstrate that research information which is vital to the advancement and practice of medicine is generated from within the inner research shells. Thus, the basic biomedical science research shell provided greater research information to the outer shells, applied biomedical science provided greater research information to the remaining outer research shells and clinical research shell provided greater research information to clinical practice than the other way around.

(b) The values of the dependency ratio increased as one moved from the inner research shells toward the outer research shells. For example the dependency ratio

between shells 1 and 2 = 4.99

between shells 1 and 3 = 6.33

between shells 1 and 4 = 38.53

between shells 2 and 3 = 1.46

between shells 2 and 4 = 9.43

between shells 3 and 4 = 6.23

These results seem to suggest that the less research oriented biomedical science research shells depend more on the research information generated by the more research oriented shells than the other way around. The degree of dependency increases as the gap between the research orientation widens. This leads one to speculate that anything done to undervalue the position of basic biomedical science research shell in the overall development of biomedical science will by implication affect the general advancement and practice of medicine.

With the decrease in the number of citations from the basic biomedical science research shell into other shells, the existence of certain problems in the channels used for the dissemination of research information is suggested. Some of the problems within the channel of communication of scientific literature have been attributed to the presence of literature sewage. Chernin, beautifully expressed this "literature sewage" problem:

> On the other hand, some of the stuff that flows through journals represent unprocessed sewage that clogs the mind it is meant to enrich, eutrophication can smother scientists just as it does aquatic life.[13]

This led this study to advance a suggestion of controlling biomedical science literature with the view of making relevant research literature more visible to biomedical science community. The details of such suggestion is given in the concluding chapter of the study.

From the analysis of the data, the following have been demonstrated:

(a) There was found to be a bi-directional flow of research information within the universe of biomedical science. The number of citations from the inner research shells were consistently greater than the number of citations from the outer research shells.

(b) The dependency ratios of outflow to inflow of citations within the universe of biomedical science were consistently greater than 1. (For example from shell 1 to 2, 3, 4, the ratios are 4.99, 6.33, 38.53 respectively.) This also demonstrated the truth of the hypothesis that research information flow from basic biomedical science research shell in the direction of clinical practice research shell.

(c) The flow of research information from basic biomedical research shell into other biomedical research shells decreased as one moved from the most basic biomedical science research shell to the most practice oriented research shell. This finding seemed to suggest the existence of a barrier which influences the flow of research information from inner research shells to the outer research shells.

(d) There was a high and increasing dependency ratio as one compared the flow of citations from basic biomedical science research shells with the flow of citation from other research shells by taking that of shell 1 with each of the shells in turn. This finding seems to show that basic

biomedical science research shell provided a core of research information necessary to stimulate the growth of biomedical science and its practice.

(e) There was a greater number of self-citation in basic biomedical science research shell than in any of the other research shells. This finding supported the notion that basic biomedical science research orientation is different from clinical medicine. This difference could be attributed to differences between the goals and missions of each part of the universe of biomedical science. While the basic biomedical science research activities originate mostly from a non-mission oriented approach (that is, the research activities are not targeted towards finding a solution to existing problems but finding fundamental laws that govern biological behaviors which may or may not lead to the advancement of biomedical science as a whole), that of clinical medicine are targeted toward finding the solutions to medical problems by using some of the existing body of knowledge.

The Anomaly

Although the results seem to show that the "effective direction" of flow of citations is from basic biomedical science research shell end of the continuum to clinical practice research end, the interactions between the basic research shell and other research shells in terms of the flow of citations across each research shell diminished significantly. This raises the question whether there is significant inter-

action between basic research and technological innovations. The results of case studies with Acronym TRACES,[14] Interactions of Science and Technology in the Innovative Process: Some Case Studies, prepared by Battelle Columbus Laboratory,[15] and Comroe and Dripps' "Scientific Basis for the Support of Biomedical Science" supported the existence of significant interactions between the basic research and technological innovations. However, while the results of the present study showed that the effective direction of research information is from basic research to clinical practice, it also demonstrated that the degree of interaction between them in terms of the flow of citations was very small. The findings seemed neither to support the notion of basic biomedical science research leading to technological (clinical practice) innovations nor that technological innovations have basic research roots.

This anomaly may be adduced to three possible explanations:

The methodological approach of this study which was based on using the flow of citations within and across different research shells to address the degree of interaction and the nature of flow of research information seemed to be an inadequate method to study the complex problems of interactions between basic research and technological innovations.

A second explanation may be that there are no significant interactions between basic research and technological inno-

vations. Therefore, the results of past studies and my own personal intuition that there exists such interactions may have been based on overly optimistic assumptions.

A third explanation is that a more sophisticated citation analysis method may be necessary to study the complex problems of interactions which may or may not exist between basic research and technological innovations.

In regard to the citation analysis method used for this study, the interaction was simply defined in terms of the flow of citation between one research shell and another. The possibility of percolating slowly over a period of years of the citations from shell to shell was not taken into account. Thus, the seeming small interaction especially between basic biomedical science and clinical research shells may be due to this over-simplistic definition of interaction. Can a complex method of citation analysis be developed to address a broader problem of interaction between basic research and technological innovations? It can be conjectured at this stage that a method involving "citation of citations" may lead to a deeper understanding of the problem of the interactions.

There may be other interaction variables relating to the flow of research information which cannot be easily reduced to citation analysis but which may influence the interactions between basic research and technological innovations. Literature glut may contribute to high self-citations. The more there are references to use in a given research shell, the

less there may be time to look for more from outside that shell. It may also contribute to the submersion of quality research information necessary for citations in a research shell. The milieu of basic research and technological innovations which probably give rise to different languages of writing and communication may contribute to the difficulty that exists in the problem of interactions. It can be hypothesized that, for an effective interaction between one research shell and the other, the language of writing of one has to be learned and assimilated by the other. The hypothesized language barrier arises as a result of the findings which showed that the nearer shells are in research orientation, the greater the flow of citations between them.

In general therefore, it can be hypothesized that the problems of interaction between basic research and technological innovation do not only involve those elements which can be defined through citation analysis alone but they also involve other communication variables as well.

Effect of Increase in Size of Research Literature on the Flow of Research Information

One of the relationships to be tested in this study is the effect of increase in size of research literature generated by the basic biomedical science research shell, on the flow of citations from it into the four biomedical science research shells. If all things were equal, one

would expect that by increasing the size of research literature (in this case, the number of research journal and source articles) there should be a corresponding increase in the number of citations generated and utilized. This should in turn increase the probability of greater flow of research information (citations) within and across various biomedical science research shells. Reasons for these expectations were based on the fact that, the more research journals with their corresponding research articles are generated, the more citable articles there should be for utilization by the different research shells. However, the above expectations have never been realized. On the contrary, it seemed that it becomes more difficult for the scientific community in general and the biomedical science community in particular to obtain relevant research information which have been buried in the sea of unused research literature. This state of affairs had led Amitai Etzioni[17] to editorialize the need for the establishment of "quality filters" to screen out the repetitive and low quality papers that burden and pollute the universe of research literature. It was Quine who complained that, "The mass of professional journals is so indigestible and so little worth digesting that the good papers, though more numerous than ever, are increasingly in danger of being overlooked."[18]

The degree to which an increase in size of research literature affected the flow of research information across biomedical science research shells was examined by develop-

ing a table which arranged the journals and/or research source articles into journal groups according to their order of productivity. Table XX illustrated the number of research journals with their corresponding number of source articles in each journal group. The grouping of the journals was done following Bradford's principle.[19] Bradford's principle is essentially based on the notion that there is a small group of core research journals or core-research articles that account for a substantial percentage of number of citations generated or utilized in the universe of scientific literature. Thus, the most highly productive journals or research articles have the greatest number of citations per unit. The one hundred five research journals in basic biomedical science research shells were grouped into four groups of approximately equal numbers of citations and these groups were ranked according to productivity in terms of the number of citations in a group. The group called "ALL" represented the productivity of all the journals combined.

An examination of Table XX shows that the most productive journal group (1) has the greatest number of citations per journal and per source article respectively (see Columns D and E). The number of journals and source articles increased in each journal group as the productivity of each journal group decreased. Thus, to have approximate equal number of citations in group (2) as in group (1), the number of journals and source articles increased to 7 and 7,156 respectively; group (3) increased to 25 and 8,734; and group 4

Table XX: The Relationship of the Number of Journals and Source Articles With the Total Number of Citations From Them, the Number of Citations Per Journal and Per Article in Each Journal Group

Rank of Journal Group From Research Shell 1 According to Productivity Group	Number of Journals A	Number of Source Articles B	Total Number of Citations From the Journal Group or Source Articles C	Number of Citations Per Journal in a Group $D = \frac{C}{A}$	Number of Citations Per Source Articles in a Group $E = \frac{C}{B}$
1	3	4,867	294,097	98,032	60.43
2	7	7,156	294,896	42,128	41.21
3	25	8,734	294,976	11,799	33.77
4	70	14,845	294,012	4,200	19.81
All	105	35,602	1,177,981	11,219	33.09

A = Number of journals per journal group that generate approximate equal number of citations;
B = Number of source articles per journal group that generate approximate equal number of citations;
C = Total number of citations from the journals in each journal group;
D = C/A = Number of citations per journal in each journal group;
E = C/B = Number of citations per source article in each journal groups; and
All = Combined effects of (ALL) journals and articles.

increased to 70 and 14,845. The number of citations per journal and per source article as shown in columns D and E revealed a decrease from 98032 citations per journal and 60.43 citations per article to only 4,200 citations per journal and 19.81 citations per article. The group (ALL) has 105 journals and 35,602 source articles and these generated 1,177,981 citations. The values of D and E in the group (ALL) were 11,219 and 33.09 citations respectively. These findings above seemed to support and demonstrate the evidence of the existence of Bradford's principle.

It could be deduced from these findings that increasing the number of journals or source articles in a given journal group without increasing its level of productivity did not increase the number of citations in each group and it even lowered the number of citations per journal and per source article respectively. This seened to point to a probable existence within each journal group some factors which according to this study might be attributed to literature pollution arising from increase in size of research literature without increase in quality.

Considering the total number of journals and source articles in group (ALL) with their corresponding number of citations per journal, it was possible to argue and calculate sets of coefficients (k) of the factors which seemed to influence the number of citations per journal.

If the productivity in terms of citations per journal was the same as the productivities of all others, then the

number of citations per journal in each group would be equal. And, the literature size required to produce the same number of citations would be equal in all the groups. Let

$$K_n = \frac{\text{Number of citations per journal in Group (ALL)}}{\text{Number of citations per journal in other group}}$$

n = ranking position of the journal group

Thus, $98032K_1 = 11.219$; $K_1 = 0.1144$

$42128K_2 = 11.219$; $K_2 = 0.2563$

$11799K_3 = 11.219$; $K_3 = 0.9508$

$4200K_4 = 11.219$; $K_4 = 2.6712$

The coefficient (K) which increased as the number of journals in a journal group increased seems to provide another approach of looking at Bradford's law of distribution of subject literature.

To examine the question concerning the flow of citations from each journal group to the four research shells, Table XXI was prepared. Using the 6' x 6' input-output citation matrix table prepared for this study, the one hundred five journals belonging to the basic biomedical science research shell were arranged into four groups ranked according to their productivity along the vertical columns. The journals belonging to each of the four research shells were arranged along the horizontal row. The actual number of citations from each group were collated (see Columns H). The respective number of citations from each journal group to the four research shells was determined by dividing the actual

Table XXI: The Relationship of the Actual Number of Citations From Each Journal Group and the Number of Citations in Each of the Given Research Shells

Number of Journals in Each Journal Group A	Actual Number of Citations Made by All Research Shells to Shell 1 in Each Journal Group to Shell 1 H	Flow of Citations per Journal Within Each of the Given Research Shells			
		Shell 1 N = 50 $\frac{H_1}{50}$	Shell 2 N = 40 $\frac{H_2}{40}$	Shell 3 N = 35 $\frac{H_3}{35}$	Shell 4 N = 25 $\frac{H_4}{25}$
3	134,643	2323	429	36.15	2.67
7	135,673	2361	409	34.23	2.73
25	133,969	2370.5	370.75	23.45	1.11
70	136,096	2436.7	339.5	18.9	.77
105	540,381	9402.75	1612.8	154.35	12.6

A = Number of journals in each journal group.
H = Actual number of citations made by all research shells in each journal group.
Thus, $H = H_1 + H_2 + H_3 + H_4$.
$H_1/50$, $H_2/40$, $H_3/35$, and $H_4/25$ depicted the number of citations generated by the journals in journal group flowing into research shell.

number of citations in each group by the number of journals per shell.

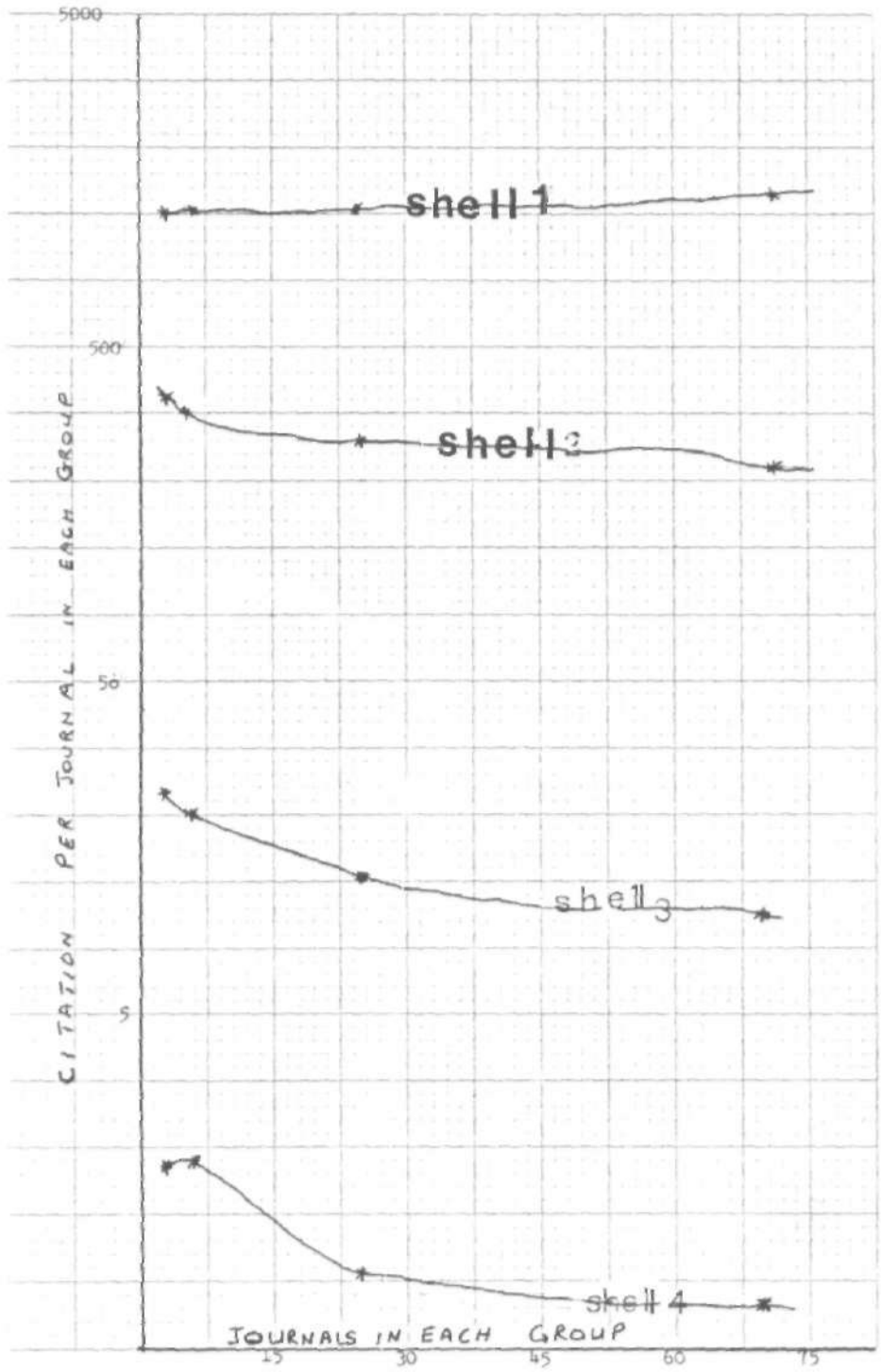
Considering each of the horizontal rows which represented the number of citations from the journal group into each of the research shells, the table revealed that the most productive journal group provided greater number of citations to each of the research shells. The number of citations per journal flowing from each of the journal groups to research shell 1 showed an increase from 2323 citations in group containing three journals to 2436.82 citations in group containing 70 journals; in shell 2, the number of citations per journal flowing from each journal group decreased from 429 to 339.56; in shell 3, it decreased from 36.15 to 18.9; and in shell 4 it decreased from 2.67 to 0.77.

These results seem to demonstrate that as the number of journals in each group increases, the flow of citations per journal increases only in shell 1. This by implication seems to indicate that experts in this shell use a wider range of research information than experts in other shells. It is to be noted also that the flow of citations was from basic biomedical science shell into basic biomedical science (self citation). This result suggests that the more research information is exposed to the experts in the basic biomedical science shell from their own research shell, the more they cite.

Considering the horizontal rows, the values of flow of citations, in the first two groups (with three journals,

seven journals respectively) are higher than the values of the last two rows (with 25 journals, 70 journals respectively). Why this is so, can be conjectured to be attributed to the fact that the more productive journals provide greater citable and useful research information than the less productive ones to applied biomedical science research, clinical research, and clinical practice research shells. The graphical representation (see Fig. 3) of the number of citations per journal flowing into each of the research shells against the number of journals in each of the journal groups revealed a small increase in the number of citations per journal as the number of journals in journal group increased in shell 1. There were decreases in the other shells. These suggest that without an increase of productivity in journal groups, the flow of citations into other research shells within the universe of biomedical science was hampered. At this point, it might be speculated that exponential law of growth of research literature beautifully expressed by Price[20] seemed to have both "negative and opposite effects" on the flow of citations from one research orientation to another within the universe of scientific literature. Whether "this negative and opposite effects" as a result of exponential growth of research literature has any direct effect on the quality of scientific research activities could not be concluded from this observation. Another study with different hypotheses would be needed to examine the relationship of quality of research and the observed decrease of citations.

Figure 3: The Number of Journals in a Group Versus Number of Citations per Journal Flowing into Each Research Shell.



However, the complaints of many scientists in general and biomedical scientists in particular seemed to point to the fact that there are a number of problems in the channels of scientific research communication brought about as a result of literature proliferation or literature exponential growth. The late Professor William Bulloch,[21] speaking as a pathologist, described this proliferation as definitely malignant - the journalistic blastoma. Writing how this growth of scientific literature certainly has brought unhappy results into the channel of scientific research communication, Theodore Fox, former editor of Lancet, in his book Crisis in Communication: The Functions and Future of Medical Journals, stated:

> When there were only a few journals, the system was relatively efficient, because new information published in any one of them probably reached everybody interested in its subject. But today, so much is printed in so many places that mere publication of a fact or idea does not by any means ensure that it will reach all the people who need it for their practice or their researches. Pearls of great price are cast before regular subscribers but often remain hidden from those who require them to complete some particular necklace of knowledge.[22]

The problem of exponential growth of scientific literature, compounded by the proliferation of scientific specialization seemed to have become a natural law of scientific enterprises. At the concluding chapter, a method will be advanced to exploit computer technology in synthesizing and

filtering research information for the production of quality research information.

Considering the vertical columns of Table XIX, the flow of citations from each group into research shells decreased from shell 1 to shell 4. This decrease was consistent with the earlier findings that the flow of citations from basic biomedical science research shell to all other research shells decreased by phenomenally large numbers, as one moved away from basic biomedical research orientation. Thus, the interaction between one research shell and the other in terms of citations flow depended on the "relative distance" between one research orientation and the other. This finding as earlier stated seemed to suggest an existence of "barriers" that prevented or dragged the flow of research information across the research shells. The notion of existence of "barriers" which are speculated to prevent or drag the flow of research information seem to be related to the quantity of research literature. It has been noted that valuable research information is prevented from reaching the source of needs because it is buried in a deluge of irrelevant research literature.[23] It can be hypothesized that the "barriers" may be partially caused by the existence of "different language of writing" of results of research projects. Most of the research write-ups invariably follow certain defined rules and regulations existing within the given research shell. Thus, to interact effectively, the language of writing of one research shell has to be learned and under-

stood by another research shell. Methods for reducing the effects of barriers to the flow of research information between one research shell and another needed another form of gate keeping system using the capability of computer technology. The details of these methods are given in the concluding chapter.

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CHAPTER SIX

SUMMARY, IMPLICATIONS, POSSIBLE APPLICATIONS, CONCLUSIONS AND SUGGESTIONS FOR FURTHER STUDY

Introduction

The fundamental basis needed to be established to pursue this study was whether, within the universe of biomedical science, there existed different research orientations (research shells) which could be identified and classified by biomedical science experts using research literature generated in the field. To do this, a guideline needed for the classification of research literature into defined research shells by biomedical science experts was designed. Having established the existence of research shells within the universe of biomedical science, the result was used to examine the hypotheses and to answer some questions raised in the study.

The central purpose of the study was to determine the quantitative differences in the flow of research information between one biomedical science research shell and the others. In this way, it was possible to determine how significant these differences were between the flow of citations from basic biomedical science research shell to each of the other biomedical science research shells and from each of the others to the basic biomedical science research shell.

The summary, implications, possible applications, and the conclusions of this study are presented in the sequence in which the materials were analyzed and discussed in Chapter Five:

(a) Research shell classification scheme and the biomedical science experts;

(b) Comparison between "research shell" and "research level" classification schemes;

(c) The dynamics of the flow of citations within and across research shells; and

(d) The effect of the increase of research literature on the flow of citations across the research shells.

Research Shell Classification Scheme and Biomedical Science Experts

The study demonstrated clearly that there exist different biomedical science research orientations within the universe of biomedical science. The experts agreed that four biomedical science research orientations (research shells) exist within the universe of biomedical science, as demonstrated by the nature of literature generated and utilized. It was revealed that the literature of biomedical science can be used to classify the different research orientations.

Three hundred fourteen biomedical science research journals were classified by the experts. Out of the

remaining thirty-six journals which were not included in the study, fourteen were not classified and twenty-two were classified by three experts into three different research categories. The experts recognized and stated that every biomedical science research journal has a central objective directed toward a unique readership and biomedical science research orientation: basic research, applied research, technological research, and practice.

The results of the analysis of the flow of citations in and out of each research shell supported the evidence of the existence of different research orientations (research shells) within the universe of biomedical science. The analysis revealed that in terms of the number of citations per journal flowing from each research shell to all others, the basic biomedical science research orientation has the greatest number of citations per journal (9033) (46.71%); this was followed by applied biomedical research shell (4483) (23.18%); clinical research shell (3543) (18.32%); and clinical practice research shell (2278) (11.78%).

Also, differences in terms of the number of source articles generated in each of the research shells supported the notion of research orientations. The basic biomedical science research shell was seen to generate more research journal articles than any of the other research shells and these decreased as the research orientation moved from the most basic to the most practical oriented research. These findings led to suggestions that the basic biomedical

scientists have greater research activities than those of the other research orientations. This characteristic led Deutsch[1] in his detailed qualitative analysis of the structure of science to refer to basic scientific research as a tightly integrated system. Feeding some empirical evidence into the qualitative analysis of Deutsch, Storer[2] introduced the concept of "hard science" as those belonging to the basic science and "soft science" as those belonging to the applied and technological sciences. Using the citation pattern of scientific knowledge, Price[3] found that basic scientific research was higher in hierarchy (putting them on the sclae of 1-10) than the soft sciences.

The identification of research shells defining the four research orientations within the universe of biomedical science could be used by biomedical science planners to redefine the missions, the purposes, and the objectives for establishing biomedical science research and medical centers. Thus, at the planning or general development stages, the biomedical science research and medical centers could be planned and organized in line with one or a combination of several research orientations. If the emphasis of one biomedical science research or medical center is basic biomedical research, then policy formulation should emphasize the nature of the research orientation. If it is more of a combination of all the research orientations or more toward direct application of research results in the practice of medicine, policy should reflect that research orientation accordingly.

By implication, such redefinition of missions, purposes, and objectives for establishing biomedical science research centers will aid biomedical science information specialists and medical librarians to formulate research information development policy that emphasizes collection of research literature relevant to the immediate needs of the research literature relevant to the immediate needs of the research orientation. In this way, funds could be conserved for and channeled to the development of quality and relevant research literature in a particular research center.

However, the generality and validity of this "research shell" classification by only one hundred twenty biomedical science experts from only one medical school in the United States are limited. Without further verifiable study on a wider cross-section of the population of biomedical science experts, the acceptance of this classification should be treated with caution. These findings undoubtedly suggest approaches to future study to be carried out on a larger scale. Such study should not limit the population of biomedical scientists to a single medical school but should include as well other biomedical scientists and medical doctors in other biomedical science research centers.

Comparison Between "Research Level" and Research Shell Classification Schemes

The comparative analysis of research journals classified by Narin into different research levels and the

research shells developed for this study found that the classification were in essential agreement. More than ninety-four percent (94.4%) of the research journals classified by experts into research shell 1 (basic biomedical science research) agreed with that of Narin's research level 4 (basic biomedical research). More than eighty-six percent (86.3%) of the research journals classified by the experts into research shell 2 (applied biomedical science research) agreed with that of research level 3 (clinical investigation). About seventy-three percent (73.90%) which were classified as clinical research shell 3 agreed with research level 2 (clinical mix). And finally, more than sixty-six percent (66.7%) of those classified as clinical practice agreed with that of research level 4 (clinical observation). The statistical analysis to test the strength of the agreement between the two classification schemes found a relatively high value of the Pearson Product Moment Coefficient of Correlation r (r_{xy} = 0.885, for P = 0.001; r = 0.174).

It is to be noted that the "research level" classification of Narin was developed by analyzing the citation patterns of each of the research journals within the universe of biomedical science. Mindful of the limitation of "research shell" classification, the strong agreement between the two classification schemes lends support to the existence of research shell classification within the universe of biomedical science, suggesting that a combination of the

two methods of classification using research journals could profitably lead to the development of a classification system different from the traditional systems which would be more relevant for the organization of scientific literature in general and biomedical science in particular.

Interactions Between Research Shells

The results of the study of the interactions between each of the biomedical science research shells in terms of the number of citations flowing from one research shell to the others demonstrated the rapidly diminishing degree of interaction. As the research orientations of the shells move further apart, the interactions between them in terms of the number of citations flowing in and out decreases dramatically.

Thus, the applied biomedical science and basic biomedical science research shells have greater interaction with one another than do the basic biomedical science and clinical practice research shell. These two opposite ends of the universe of biomedical science are separated by two other research orientations called applied biomedical science and clinical research.

The questions which could be raised from these findings include:

(i) Does the existence of applied biomedical science and clinical research shells between basic biomedical science and clinical practice research

shells act as barriers to the flow of citations between the two ends of research orientations?;

(ii) If so, how can the effect of these barriers be reduced so that enough relevant and quality research information could flow between basic research and practice?;

(iii) Does the apparent existence of this relatively small interaction suggest a well defined existence of independence between the two research shells?; and

(iv) Can their interaction actually be properly measured in terms of direct citation exchange between them?

Answers to some or all of the questions raised above and which this study was not set to examine undoubtedly will provide a better understanding of the complex question of interaction.

Dynamics of the Flow of Citations

Examining the dynamics of the flow of citations within and across the different research shells with the purpose of testing the central hypothesis, finding the "effective direction" of the flow of research information and the dependency relationship between one research shell and the others, the results demonstrated that the number of citations flowing from the basic biomedical science research shell to

any of the outer research shells were consistently greater than those flowing in.

This thus proved the central hypothesis that the quantity of research information from the basic biomedical science research shell to all the other outer research shells is significantly greater than those from outer research shell to basic biomedical science research shell. This also demonstrated the existence of "effective direction" of the flow of research information within the universe of biomedical science. The universe of biomedical science research enterprise being made up of four research orientations (research shells), at one end of the continuum of which lies the basic biomedical science research and on the other end the clinical practice research shell, the flow of research information from the basic biomedical science end towards the clinical practice end was seen to be greater than those from clinical practice end toward the basic biomedical science end. The number of citations from basic biomedical science into the three outer research shells was 186150.88 and those from the three outer research shell into the basic biomedical science shell was 33502.28. Thus, the citations flowing from the inner research shell to outer research was about 5.56 times the one flowing in. Considering applied biomedical science research shell, with respect to two outer shells, the citations flowing from this to the remaining two research was about 2.16 times the one flowing from the two outer shells to the applied bio-

medical science research shell. And lastly considering the flow of citations from clinical research shell into clinical practice research shell, there was about 6.23 times those that flowed from clinical practice to clinical research. These findings demonstrated that the flow of citations from the inner research shells were consistently greater than those flowing in from the outer shells. This proved the "effective direction" of research information from the basic biomedical science research end toward the clinical practice research end of the universe of biomedical science.

Considering the dependency relationship of one research shell on the others, the results seem to demonstrate that all the research shells depended heavily on the information generated from basic biomedical science. Surprisingly, the clinical practice research shell depended on basic biomedical science research shell more than 38 times. (That is, clinical practice research shell uses 38 times more research information from basic biomedical science research shell than basic biomedical science uses from the clinical practice research shell.) Clinical research shell uses 6.33 times and applied biomedical science research shell uses 4.99 times from basic biomedical science research shell. These findings seemed to demonstrate the fact that basic research information is vital to the advancement and practice of medicine. Thus, the basic biomedical science research shell provided greater research information to outer

shells, applied biomedical science research shell provided greater research information to the remaining two outer research shells; and clinical research shell provided greater research information to clinical practice than the other way around.

The decrease of the flow of the number of citations from the basic biomedical science research shell into outer research shells seemed to suggest the existence of problems in the channels used for the dissemination of research information. Some of the problems within the channels of communication could be attributed to the presence of "literature sewage" brought about by the proliferation of both the high quality and poor quality research literature. The high quality research literature are submerged in the poor quality research literature and this could be said to result in clogging the channels of communication. Whether the presence of literature sewage led to the observed decrease in the flow of research information between the research shells is difficult to conclude from the results of this study without further verification.

Following the establishment of the universe of biomedical science as made up of research shells and each shell representing a unique research orientation, the findings of this study suggest the existence of a unique research shell "language" employed to conduct, report, and publish research results. The finding of high self-citations characteristic of each research shell seems to support the

existence of these hypothesized different forms of language. Perhaps this research shell language has to be learned and assimilated by other research shells before there can be proper communication between them, and within the context of this study, before there could be greater flow of citations between them. This notion of the existence of research shell language arose from the finding that the number of citations exchanging between any two research shells were consistently greater than those that are further apart. However, the existence of "research shell language" remained speculative until more work is done to establish the validity of the concept and the multivariate forms of interactions between them.

Spanning, connecting, integrating, and synthesizing research literature generated in each of the research orientations within the universe of science have always been the task of librarians, information scientists, indexers, and documentalists on the one hand and the generators, producers, and the users of research literature on the other. The generator, producer, and the user of research literature have played a major role in providing a gate keeping system through reviews, analysis, and classification of past research works. Through these various activities, it has been possible to identify research fronts and the most active research areas of science.

The findings of the existence of research shells within the universe of biomedical science, did not only

reveal the critical tasks of the librarians and information scientists, but also suggested the complex nature of interactions between the research orientations within the universe of knowledge.

It has been alluded to, from the results of this study that there existed barriers in the channels of communication between the various research shells in the universe of biomedical science, possibly as a result of literature sewage and the probable existence of research shell languages. In order to reduce or control the barriers between the research shells, the research literature not only has to be filtered to delete poor quality research literature, but each research shell language employed to generate its research literature has to be translated into the language of the other shells, assuming that there are such languages. Thus, the basic, fundamental and theoretical language characteristic of the basic biomedical science research shell has to be translated into the language of the applied biomedical science research shell or clinical practice research shell. As to who would do such translation would have to wait for further studies and understanding.

Concerning the notion of filtration of research information to delete poor quality research literature, the results of this study seemed to indicate that the development of a Computer Information Filtering System is highly possible.

It must be mentioned, however, that "information privacy" combined with human desire for personal recognition

as against service to humanity may pose real problems to the development of such a computer system. It seems that to incorporate personal recognition capability in such a system may not be difficult. The international characteristics of biomedical science body of knowledge and its value for the whole human community call for sacrifice on the part of the generators and processors to develop an information filtering system which will maximize the visibility of quality research information to all scientific community in general and to biomedical science community in particular.

The notion of devising a research information filtering system to enhance "information quality control" may make some information scientists and librarians nervous because of its seeming implication for censorship. The system does not suggest a change in the basic ecology of biomedical science literature. Rather, it suggests that the barriers or factors affecting the flow of quality and relevant research information be controlled to effect a better filtering system.

The description of the information filtering system that follows is merely speculative and it is open to further studies and investigation.

With the growing interest of computer and telecommunication technologies in information transfer[4, 5] authors like Lancaster[6] argued forcefully for a paperless information system and Plotkin[7] left university teaching in 1980 to found a Manhattan-based company known as Comtex Scientific.

Comtex hopes to offer the first line of twenty-two electronic journals which are stored in a central computer ready to be retrieved via telephones by scientists who own mini- or microcomputers.

And the present availability of information data bases[8] and the existence of comprehensive citation indexes of all fields of science[9] make the development of a multipurpose computer information system highly probable. This system would take into account the existence of the "language" gap between research shells, the proliferation of good quality and poor quality research literature, and the existence of research shells within the universe of biomedical science.

Using the existing Science Citation Index of the Institute for Scientific Information[10] as a data base, the research journals, monographs and books which are indexed could be neatly grouped into their various research orientations (shells). In this way, it would be possible to monitor the growth of research literature in a research shell with respect to other research shells.

Since citations of particular research articles or journal belonging to a particular research shell provide links with articles or journals in another research shell, information pertaining to the nature of the relationship between the cited and citing articles within and across the research shells could be established by computer connecting capability. Such computer connecting analysis would help to eliminate those that have little or no citing and cited

interaction. Invariably, such computer connecting analysis could lead to filtering all the poor quality research literature away.

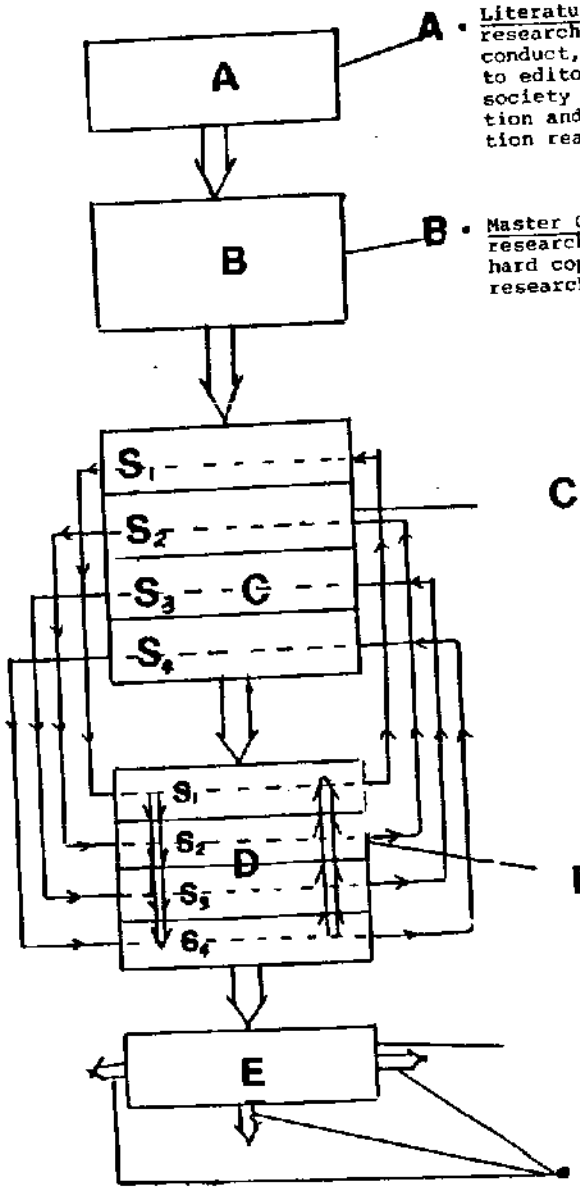
To bridge the language gap, both the computer and bio-, medical science experts on the one hand, and the librarian and information scientists on the other would have to work together to provide the right type of language translation needed between one research shell and another.

Diagrammatically, this hypothetical Computer Information Filtering System could be represented as illustrated in Figure 4.

The Effect of Increase of Source Articles on the Flow of Number of Citations

The findings of the study as related to the effect of increase of source articles or research journals on the pattern of flow of citations from one research shell to another gave evidence to support that an increase of either source articles or journals without a corresponding change in their productivity affected the flow of citations. Arranging the research journals into journal groups with their corresponding source articles and the number of citations according to their citation productivity showed that the highly productive journal group provided a greater flow of citations. The citation flow per journal decreased as the number of research articles or journals increased. These findings supported Bradford's principle that only a few

Figure 4: Diagramatic Representation of Computer Information Filtering System



A. Literature Generator and Processor Unit represent the origin of research literature. Authors, researchers, or writers originate, conduct, and finally write out the research results. These are sent to editorial board of a chosen publishing organization or scientific society for possible evaluation. The publishers, through recommendation and advice of the editorial board prepare the research information ready for publication.

B. Master Computer Record Unit allows the final accepted draft of research information to be copied instead of publishing it into hard copy. This is a computer recording system in which each research literature is given a unique code of identification.

C. Classification Unit provides classification capability in which the research literature in the master computer record unit are classified into the research shell classification.

D. Filtering Unit provides the means of spanning, sorting, synthesizing and connecting the research literature in each research shell. The filtering capability thus provides method of retrieving research literature from each of the research shells.

E. Output Unit provides an output for either the filtered research literature or research literature from any of the units.

Computer Terminal.

highly productive journals or articles accounted for more citations in any given research orientation. The findings tended to support a probable existence within each journal group, some factors which could be attributed to literature sewage. Thus, an increase in size of research literature without an increase in productivity (quality) lowered the flow of citations across each research shell.

Arrangement of research journals according to productivity ranking have been employed in the past to develop core-research literature.

The findings led to the establishment of coefficient of productivity of each journal group. The highly productive journal group was found to have lower coefficient of productivity. This could be extended to finding that of single research journal, monograph, or book which has the probability of citing and being cited. The coefficient of productivity of journal, monograph or book describing the quality and productivity of the research information described in it could help bring together all the good quality and poor quality research literature and thus enhances the filtering system.

Suggestions for Further Study

A number of problem areas were identified throughout the development of this study which are deserving of further investigation.

1. Study of the structure of biomedical science and the pattern of the flow of its research information based on the universe of biomedical science as essentially made of four research shells representing the different research orientations and practice is severely limited. The interactions within and among different research orientations, the pattern of communication between basic research, applied research, clinical research and practice within biomedical science form a complex multitude of variables (e.g. research orientations, pattern of literature generated and utilized, the nature of communication among various research and practice categories, etc.). In a study to get a broad based view of these complex interactions, there is a need to develop multivariate statistical analysis of the system.

2. The existence of barriers which resulted in the slowing down of the flow of research information has been alluded to in the study. There is a further need to study to determine the factors that contribute to the slowing down of the flow of research information as the volume of research information increases.

3. Citation analysis has been applied in several different ways to study the structure of the literature of science, but there have been no attempts made to develop a means of identifying coefficient of productivity for each research literature in the universe of science. The combined use of experts, productivity, and citation patterns of each research literature can be employed to identify such coefficients.

4. The discovery of the existence of research shells within the universe of biomedical science would no doubt help to find a theoretical answer to the classification of scientific knowledge in general and biomedical science in particular. Using the concept of "research shell" classification to do this needs further study.

5. In the study, it was suggested that a Computer Information Filtering System be developed to aid in sorting, synthesizing, and classifying the biomedical science literature into its various research orientations. Such a development would make relevant research information more visible to all biomedical science community. There is a need to investigate the possibility of such a computer system.

6. It was identified that the direction of flow of citations was always from the basic oriented research to practice oriented research. One does not know however, whether this outflow of citations from basic to practice research is influenced by the nature of the channels of communication.

(a) Is the number of flow of citations for each research shell consistent with time?;

(b) What is the effect on the flow of citations if funding of a particular research orientation is decreased?;

(c) What essential roles do review journals play in the dissemination of research information?;

(d) Can citation analysis provide a true and valid measure of interaction between research shells?

8. It appears from the observation that, the closer two research shells were, the greater they were able to assimilate the "language of writings" of each other and thus communicate better. There is a need to explore if such languages exist. If they do, do they act as one of the barriers to the flow of research information in the universe of biomedical science?

Many other questions exist with regard to the interaction of various research categories. Because of its potential benefit to society in general and to biomedical and information scientists in particular, such research will certainly represent a fruitful area for time to come.

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[10]Ibid.

APPENDIX A

Cover Letter for the Guideline to Biomedical Scientists and Practitioners

INDIANA UNIVERSITY
SCHOOL OF LIBRARY
and INFORMATION SCIENCE
Bloomington, Indiana 47405
(812) 335-

Dear

I am writing to request your expert help in classifying biomedical science journals into their defined research categories.

As a doctoral candidate in the above named School of Indiana University, I am undertaking a research study of communication patterns among biomedical researchers in four research categories.

It is expected that the study will lead to a better understanding of the nature of interactions between basic biomedical science research and applied biomedical science research, clinical research, and clinical practice. It is hoped that such understanding will aid medical planners to better plan the support of biomedical science research. Also it is expected to aid information scientists and medical librarians in developing information retrieval systems that will better meet the information needs of biomedical scientists and practitioners.

It will be greatly appreciated if you could take a few minutes to go through the attached list of journals in your area of specialization and classify them according to the definition as given in the enclosed: Guideline to Biomedical Scientists and Practitioners.

The study is expected to be completed in four months time. Your early response shall be most appreciated.

A self-addressed stamped envelope is enclosed for the return of your valuable information.

Thank you in advance for your help.

Sincerely,

Daniel N. Obaka

APPENDIX B

Guideline to Biomedical Scientists and Practitioners

In an effort to understand more of the patterns of communication among various categories of biomedical scientists and practitioners, this study is being undertaken to examine the citation patterns of biomedical scientists as reflected in published journals. To do this, there is a need to classify biomedical science journals into four defined research categories

Journal classification of this nature may be seen to have some degree of overlap in the type of research articles published in them. If there is any journal in your field of specialization which publishes research articles from two or more biomedical science research shells, you are requested to select the biomedical research category that best describes the position of the journal. Please omit any journal that cannot be classified because of overlap.

The following are definitions of categories of biomedical science journals:

1. Basic Biomedical Science Research Journal - a journal that reports basic scientific research leading to the discovery of medical phenomena.

2. Applied Biomedical Science Research Journal - a journal that reports mission-oriented research activities emphasizing the applicability of certain existing research results to the understanding and solution of biomedical problems.

3. Clinical Research Journal - a journal that reports current research activities dealing with finding solutions to medical problems by direct or indirect experimentation on human subjects.

4. Clinical Practice Journal - a journal that reports only observational medical facts as they concern existing and ongoing medical practices without drawing any inferences from them.

A. Do you consider the given journals in your field of specialization to be reporting principally:

1. basic biomedical scientific research;

2. applied biomedical scientific research;

3. clinical research

4. clinical practice.

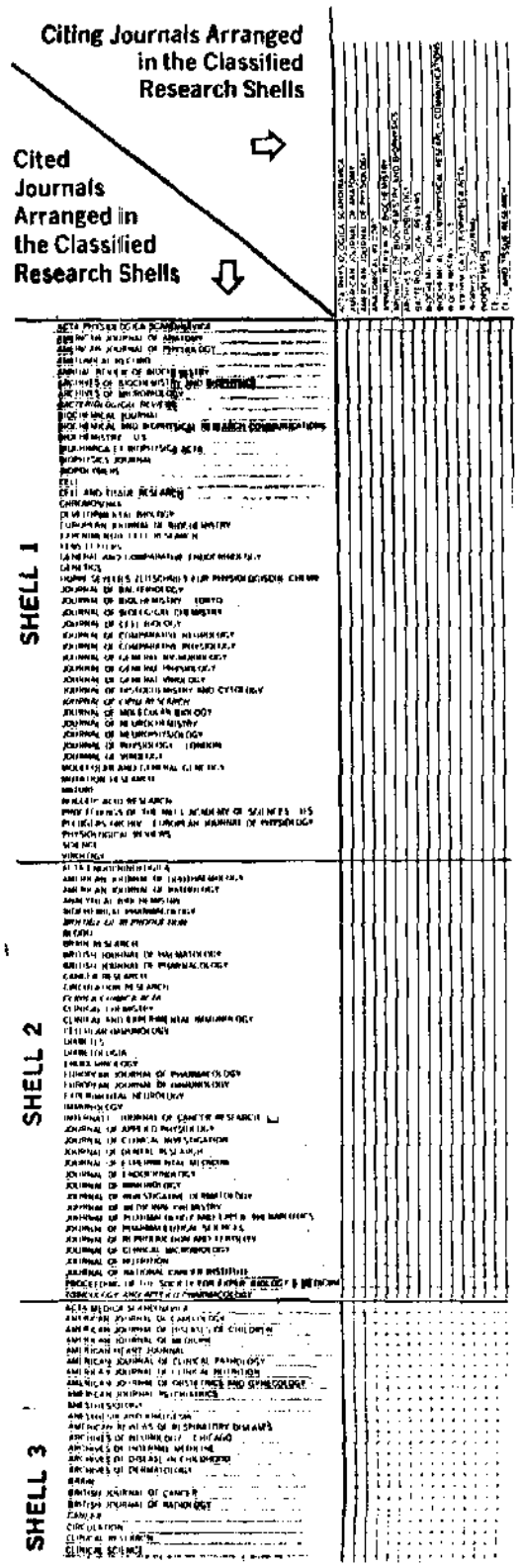
Identify by (X) into which research category each journal can best be classified according to the given definitions.

Name of Subject Field:	Categories of Biomedical Science Journals			
Journal Names	Basic Biomedical Scientific Research	Applied Biomedical Scientific Research	Clinical Research	Clinical Practice
	1	2	3	4

B. Is there any journal frequently used by you in your field of specialization but not listed? List not more than 2 and classify them accordingly.

1. _____

2. _____


Citing Journals Arranged in the Classified Research Shells
Cited Journals Arranged in the Classified Research Shells
SHELL 1
SHELL 2
SHELL 3

APPENDIX D

Names of Journals in Each Subfield Classified Into Two Classification System with Their Ratings

Names of Biomedical Science Journals	Research Shell Classification				Narin/Pinski Research Level Classification			
	S_1	S_2	S_3	S_4	L_4	L_3	L_2	L_1
ALLERGY								
1. Acta Allergologica				X(1)				X(1)
2. Annals of Allergy				X(1)				X(1)
3. Int. Arch. Allerg. App. Immunol.		X(3)				X(3)		
4. Journal of Allergy & Clinical Immunol.		X(2)						X(1)
5. Clinical Allergy OM -	ED	ED	ED	ED	NCN	NCN	NCN	NCN
6. Progress in Allergy			X(3)			X(3)		
ANESTHESIOLOGY								
7. Acta Anaesthesiologica Scandinavica OM -	NCE	NCE	NCE				X	
8. Anaesthesia				X(1)				X(1)
9. Anesthesiology		X(2)				X(2)		
10. Anesthesia & Analgesia		X(2)				X(2)		
11. British Journal of Anaesthesists		X(2)				X(2)		
12. Can. Anaesth. Soc. Journal		X(2)				X(2)		
13. Anaesthesists			X(1)					X(1)

* NCE = Not Classified by Experts
  NCN = Not Classified by Narin
  ED = Experts Disagreed
  OM = Omitted

Name of Biomedical Science Journals	Research Shell Classification				Narin/Pinski Research Level Classification			
	S_1	S_2	S_3	S_4	L_4	L_3	L_2	L_1
ANATOMY & MORPHOLOGY								
14. Acta Anatomica	X(4)				X(4)			
15. Amer. J. Anatomy	X(4)				X(4)			
16. Anatomical Record	X(4)				X(4)			
17. Journal of Anatomy	X(4)				X(4)			
18. Journal of Morphology	X(4)				X(4)			
19. Archives of Anatomy & Morphology	X(4)				X(4)			
BIOCHEMISTRY								
20. Analytical Biochemistry		X(3)			X(4)			
21. Archives of Biochemistry and Biophysics	X(4)				X(4)			
22. Annual Review of Biochemistry	X(4)				X(4)			
23. Biochemical and Biophysical Res. Commun.	X(4)				X(4)			
24. Biochemical Journal	X(4)				X(4)			
25. Biochemistry - U.S.	X(4)				X(4)			
26. Biochemica et. Biophysics Acta	X(4)				X(4)			
27. Biochimie	X(4)				X(4)			
28. Biopolymers	X(4)				X(4)			
29. Canadian Journal of Biochemical Physiology	X(4)				X(4)			
30. European Journal of Biochemistry	X(4)				X(4)			
31. FEBS - Letters	X(4)				X(4)			

Names of Biomedical Science Journals	Research Shell Classification				Narin/Pinski Research Level Classification			
	S_1	S_2	S_3	S_4	L_4	L_3	L_2	L_1
32. Hope - Seyler S. Zeitschrift fur Physiologische Chemie								
33. Journal of Biochemistry (Tokyo)	X(4)				X(4)			
34. Journal of Biological Chemistry	X(4)				X(4)			
35. Journal of Steroid Biochemistry	X(4)				X(4)			
BIOPHYSICS								
36. Annual Reviews of Biophysics and Bioengin.	X(4)				X(4)			
37. Advances in Biophysics	X(4)				X(4)			
38. Biophysical Journal	X(4)				X(4)			
39. Progress in Biophysics	X(4)				X(4)			
40. Quarterly Reviews of Biophysics	X(4)				X(4)			
41. Studia Biophysica OM -	NCE	NCE	NCE	NCE	X(4)			
CANCER								
42. British Journal of Cancer		X(3)					X(2)	
43. Cancer			X(2)				X(2)	
44. Cancer Letters OM -	ED	ED	ED	ED	NCN	NCN	NCN	NCN
45. Cancer and Chemotherapy Report		X(3)				X(3)		
46. Cancer Research		X(3)				X(3)		
47. Cancer Treatment Research		X(3)					X(2)	
48. International Journal of Cancer		X(3)					X(2)	
49. Gann OM -	NCE	NCE	NCE	NCE	X			

Names of Biomedical Science Journals	Research Shell Classification				Narin/Pinski Research Level Classification			
	S_1	S_2	S_3	S_4	L_4	L_3	L_2	L_1
50. J. National Cancer Inst.		X(3)				X(3)		
51. European Journal of Cancer			X(2)			X(3)		
CARDIOVASCULAR SYSTEM								
52. American Heart Journal			X(2)				X(2)	
53. American J. Cardiology			X(2)				X(2)	
54. Angiology			X(2)				X(2)	
55. Atherosclerosis			X(2)			X(3)		
56. Cardiovascular Res.		X(3)				X(3)		
57. Chest				X(1)				X(1)
58. Circulation			X(2)				X(2)	
59. Circulation Research		X(3)				X(3)		
60. British Heart Journal			X(2)					X(1)
CELL BIOLOGY CYTOLOGY AND HISTOLOGY								
61. Experimental Cell Research	X(4)				X(4)			
62. Histochemie	X(4)				X(4)			
63. Stain Technology	X(4)				X(4)			
64. Int. Rev. Cytology	X(4)				X(4)			
65. In Vitro-Journal of the Tissue Culture Assn.	X(4)				X(4)			
66. J. Cell Biology	X(4)				X(4)			
67. J. Cell Science	X(4)				X(4)			
68. J. Cell Physiology	X(4)				X(4)			
69. J. Histochem. and Cytochemistry	X(4)				X(4)			

Names of Biomedical Science Journals	Research Shell Classification				Narin/Pinski Research Level Classification			
	S_1	S_2	S_3	S_4	L_4	L_3	L_2	L_1
70. J. Membrane Biology	X(4)				X(4)			
71. J. Ultrastructure Research OM -	ED	ED	ED	ED	X			
72. Protoplasma	X(4)				X(4)			
73. Cell	X(4)							
74. Tsitologiya	NCE	NCE	NCE	NCE	X			
DENTISTRY								
75. Archives of Oral Biology		X(3)				X(3)		
76. International Dental Journal		X(3)				X(3)		
77. J. Dental Research		X(3)				X(3)		
78. J. American Dental Association				X(1)				X(1)
79. Oral Surgery, Oral Medicine & Oral Pathology			X(2)				X(2)	
80. British Dental Journal			X(2)				X(2)	
81. Scandinavian J. Dental Research OM -			X(2)			X(3)		
DERMATOLOGY AND VENEREAL DISEASES								
82. Archives Dermatology			X(2)				X(2)	
83. J. Invest. Dermatology		X(3)				X(3)		
84. British J. Dermatology			X(2)				X(2)	
85. British Journal of Venereal Diseases		X(3)						
86. Dermatologica			X(2)					X(1)
87. Acta Dermeto - Venereologica			X(2)				X(2)	

Names of Biomedical Science Journals	Research Shell Classification				Narin/Pinski Research Level Classification			
	S_1	S_2	S_3	S_4	L_4	L_3	L_2	L_1
EMBRYOLOGY								
88. Develop. Biol.	X(4)				X(4)			
89. J. Emb. Exp. Morphology	X(4)				X(4)			
90. Teratology	X(4)				X(4)			
91. Growth	X(4)				X(4)			
92. W. Roux. Arch. Ent. Organ.	X(4)				X(4)			
93. Z. Anat. Entw. OM -	NCE	NCE	NCE	NCE	X			
ENDOCRINOLOGY								
94. Acta Endocrinologica		X(3)				X(3)		
95. Diabetes		X(3)				X(3)		
96. Diabetologica		X(3)				X(3)		
97. Endocrinology		X(3)				X(3)		
98. Gen. and Comp. Endocrinology	X(4)				X(4)			
99. Journal of Clinical Endocrinology & Metabolism		X(3)				X(3)		
100. Journal of Endocrinology		X(3)				X(3)		
101. Metabolism OM -		X(3)				X(3)		
102. Neuroendocrinology	X(4)					X(3)		
103. Hormone and Metabolic Research		X(3)				X(3)		
GASTROENTEROLOGY								
104. American Journal Digestive Diseases			X(2)				X(2)	
105. Gastroenterology			X(2)				X(2)	
106. Gut			X(2)				X(2)	

Names of Biomedical Science Journals	Research Shell Classification				Narin/Pinski Research Level Classification			
	S_1	S_2	S_3	S_4	L_4	L_3	L_2	L_1
107. Scandinavian J. of Gastroenterology			X(2)				X(2)	
108. American Journal of Gastroenterology			X(2)				X(2)	
GENETICS								
109. Genetics	X(4)				X(4)			
110. Genetic Research	X(4)				X(4)			
111. Hereditas	X(4)				X(4)			
112. Heredity	X(4)				X(4)			
113. Human Heredity		X(3)				X(2)		
114. Molecular and General Genetics	X(4)				X(4)			
115. Journal of Heredity	X(4)				X(4)			
116. Mutation Research	X(4)				X(4)			
117. Evolution	X(4)				X(4)			
118. Chromosoma	X(4)				X(4)			
119. Biochemical Genetics	X(4)				X(4)			
120. Annals of Human Genetics		X(3)				X(3)		
121. American Journal of Human Genetics		X(3)				X(3)		
GENERAL AND INTERNAL MEDICINE								
122. Acta Medica Scandinavica			X(2)				X(2)	
123. American Journal of Medicine			X(2)				X(2)	
124. American Journal of Medical Science			X(2)				X(2)	
125. Annals of Internal Medicine			X(2)					X(1)

Names of Biomedical Science Journals	Research Shell Classification				Narin/Pinski Research Level Classification			
	S_1	S_2	S_3	S_4	L_4	L_3	L_2	L_1
126. Archives of Internal Medicine		X(3)					X(2)	
127. Australian Journal of Experimental Biology and Medical Science		X(3)				X(3)		
128. British Medical Bulletin			X(2)			X(3)		
129. British Medical Journal				X(1)				X(1)
130. Canadian Medical Assoc. Journal				X(1)				X(1)
131. Clinical Chemistry		X(3)				X(3)		
132. Clinica Chimica Acta		X(3)				X(3)		
133. Clinical Research				X(1)				
134. Clinical Science and Molecular Medicine		X(3)				X(3)		
135. Clinical Science			X(2)			X(3)		
136. Deutsch Medizinische Wochenischrift				X(1)				X(1)
137. Journal of the American Medical Assn.				X(1)				X(1)
138. Journal of Clinical Investigation		X(3)				X(3)		
139. Journal of Lab and Clinical Medicine		X(3)				X(3)		
140. Journal of Medicinal Chemistry		X(3)				X(3)		
141. Journal of Medicine		X(3)				X(3)		
142. Johns Hopkins Medical Journal			X(2)				X(2)	
143. Klinische Wochenschrift			X(2)				X(2)	
144. Lancet			X(2)				X(2)	

Names of Biomedical Science Journals	Research Shell Classification				Narin/Pinski Research Level Classification			
	S_1	S_2	S_3	S_4	L_4	L_3	L_2	L_1
145. Mayo Clinical Proceedings				X(1)			X(2)	
146. Medical J. Australia				X(1)				X(1)
147. Medical Clinics of North America				X(1)				X(1)
148. Medicine				X(1)			X(2)	
149. New England Journal of Medicine			X(2)				X(2)	
150. Nouve Presse				X(1)				X(1)
151. Proceedings of the Society for Exp. Biol. & Med.		X(3)				X(3)		
152. Quarterly Journal of Medicine OM -	ED	ED	ED	ED				
153. Scandinavian Journal of Clinical Invest.		X(3)				X(3)		
154. Proceedings of the Royal Society of Medicine OM -	ED	ED	ED	ED				
155. Postgraduate Medical Journal			X(2)					X(1)
156. Schweizerische Medizinische Wochenschrift				X(1)				X(1)
HEMATOLOGY								
157. Blood		X(3)				X(3)		
158. British Journal of Haematology		X(3)				X(3)		
159. Thromboses et Diathesis Haemorrhagica OM -	ED	ED	ED	ED	NCN	NCN		
160. Thrombosis Haematosis		X(3)				X(3)		
161. Thrombosis Research		X(3)				X(3)		
162. Transfusion				X(1)				X(1)

Names of Biomedical Science Journals	Research Shell Classification				Narin/Pinski Research Level Classification			
	S_1	S_2	S_3	S_4	L_4	L_3	L_2	L_1
163. Scandinavian Journal of Haematology			X(2)				X(2)	
164. Acta Haematologica - Basel		X(3)				X(3)		
165. Vox Sanguin		X(3)				X(3)		
IMMUNOLOGY								
166. Cellular Immunology OM -	ED	ED	ED	ED		X		
167. Journal of Immunology		X(3)				X(3)		
168. Journal of Experimental Medicine		X(3)				X(3)		
169. Journal of Infectious Diseases		X(3)					X(2)	
170. Journal of the Reticulo-endothelial Society OM -	NCE	NCE	NCE	NCE		X		
171. Transplantation				X(1)		X(3)		
172. Transplantation Proceeding				X(1)		X(3)		
173. Transplantation Review				X(1)		X(3)		
174. Immunology		X(3)				X(3)		
175. Immunochemistry		X(3)				X(3)		
176. European Journal of Immunology		X(3)				X(3)		
177. Clinical and Experimental Immunology		X(3)				X(3)		
NUTRITION								
178. American Journal of Clinical Nutrition			X(2)		X(4)			
179. British Journal of Nutrition OM -	NCE	NCE	NCE	NCE	X			

Names of Biomedical Science Journals	Research Shell Classification				Narin/Pinski Research Level Classification			
	S_1	S_2	S_3	S_4	L_4	L_3	L_2	L_1
180. Journal of Nutrition OM -	ED	ED	ED	ED	X			
181. Proceedings of the Nutrition Society			X(2)		(4)			
182. Journal of the American Dietetic Assn. OM -	ED	ED	ED	ED	X			
MOLECULAR BIOLOGY								
183. Lipids	X(4)				X(4)			
184. Journal of Lipids Research	X(4)				X(4)			
185. Journal of Molecular Biology	X(4)				X(4)			
186. Nucleic Acid Research	X(4)				X(4)			
187. Molecular Biology	X(4)				X(4)			
188. Molecular and Cellular Biology	X(4)				X(4)			
189. Molecular and Cellular Biochemistry	X(4)				X(4)			
MICROBIOLOGY								
190. Annual Review of Microbiology	X(4)				X(4)			
191. Applied Microbiology		X(3)			X(4)			
192. Archives of Microbiology	X(4)				X(4)			
193. J. Applied Bacteriology		X(3)			X(4)			
194. J. Bacteriology	X(4)				X(4)			
195. J. General Microbiology	X(4)				X(4)			
196. Can . J. Microbiol.		X(3)			X(4)			
197. Bacteriol. Reviews	X(4)				X(4)			

Names of Biomedical Science Journals	Research Shell Classification				Narin/Pinski Research Level Classification			
	S_1	S_2	S_3	S_4	L_4	L_3	L_2	L_1
198. Current Topics in Microbiology OM -	ED	ED	ED	ED	NCN	NCN	NCN	NCN
199. J. Medical Microbiology			X(2)			X(3)		
200. Zentralblatt fur Bakteriologie Parasitenkunde, Infektion Krankheiten und Hygiene Erste Abteilung Originale OM -	NCE	NCE	NCE	NCE	X			
NEPHROLOGY								
201. Kidney International		X(3)				X(3)		
202. Nephron			X(2)				X(2)	
OBSTETRICS AND GYNECOLOGY								
203. American Journal of Obstetrics and Gynecol.			X(2)				X(2)	
204. Obstetrics and Gynecology				X(1)				X(1)
205. British Journal of Obstetrics & Gynecology				X(1)				X(1)
206. Acta Obstetrics et Gynecological Scand. OM-	NCE	NCE	NCE	NCE				
207. Clinic in Obstetrics and Gynecology				X(1)			X(2)	
208. Gynecologic Oncology			X(2)					
209. Archives of Gynecology			X(2)				X(2)	
210. Journal of Obstetrics and Gynecology of the British Commonwealth OM-	NCE	NCE	NCE	NCE			X(2)	
NEUROLOGY & NEUROSURGERY								
211. Acta Neuro Pathologica	X(4)					X(3)		
212. Brain			X(2)				X(2)	

Names of Biomedical Science Journals	Research Shell Classification				Narin/Pinski Research Level Classification			
	S_1	S_2	S_3	S_4	L_4	L_3	L_2	L_1
213. Brain Research		X(3)			X(4)			
214. Neurology			X(2)				X(2)	
215. Vision Research	X(4)				X(4)			
216. Journal of Neuro-physiology	X(4)				X(4)			
217. Journal of Neurochemistry	X(4)				X(4)			
218. Experimental Neurology	X(4)				X(4)			
219. Electroencephalography and Clinical Neuro-physiology - EEG Journal		X(3)				X(3)		
220. Experimental Brain Research		X(3)			X(4)			
221. Journal of Comp. Neurology	X(4)				X(4)			
222. Review of Neurology OM -	ED	ED	ED	ED				X
OPHTHALMOLOGY								
223. American Journal of Ophthalmology				X(1)			X(2)	
224. Archives of Ophthal-mology OM -	ED	ED	ED	ED			X(2)	
225. British Journal of Ophthalmology			X(2)				X(2)	
226. Acta Ophthalmologica-Kobedheufn								
227. Experimental Eye Research		X(3)				X(3)		
228. Investigative Ophthal-mology		X(3)				X(3)		
229. Investigative Ophthal-mology & Visual Res.		X(3)				X(3)		

Names of Biomedical Science Journals	Research Shell Classification				Narin/Pinski Research Level Classification			
	S_1	S_2	S_3	S_4	L_4	L_3	L_2	L_1
230. Ophthalmologica			X(2)			X(2)		
231. Ophthalmology			X(2)					X(1)
232. Klinische Monatsblatder fur Angen. OM -	NCE	NCE	NCE	NCE			X	
OTORHINOLARYNGOLOGY								
233. Acta Oto Laryngologica			X(2)				X(2)	
234. Annals of Otology, Rhinology & Laryngology			X(2)				X(2)	
235. Larynsgoscope				X(1)				X(1)
236. Archives Otolaryngology				X(1)				X(1)
ORTHOPEDICS								
237. Journal of Bones and Joint Surgery				X(1)				X(1)
238. Clinical Orthopaedics and Related Res.			X(2)				X(2)	
239. Acta Orthopaedica Scand.				X(1)				X(1)
ARTHRITIS AND RHEUMATISM								
240. Annals of the Rheumatic Diseases				X(1)		X(2)		
241. Arthritis and Rheumatism				X(1)				X(1)
242. Journal of Rheumatology				X(1)				X(1)
243. Revue du Rhumatism et de Maladies Osteo. Art.				X(1)				X(1)
PATHOLOGY								
244. American Journal of Clinical Pathology			X(2)				X(2)	
245. American Journal of Pathology		X(3)						

Names of Biomedical Science Journals	Research Shell Classification				Narin/Pinski Research Level Classification			
	S_1	S_2	S_3	S_4	L_4	L_3	L_2	L_1
246. Archives of Pathology			X(2)				X(2)	
247. British Journal of Experimental Pathology		X(3)				X(3)		
248. Experimental and Molecular Pathology OM -	ED	ED	ED	ED		X		
249. Laboratory Investigation		X(3)				X(3)		
250. Pathologie et Biologie			X(2)			X(3)		
251. Journal of Pathological Bacteriology OM -	NCE	NCE	NCE	NCE		X(3)		
252. Journal of Pathology		X(3)				X(3)		
253. Acta Pathological Scandinavica		X(3)				X(3)		
PHARMACOLOGY								
254. Archives Internationales de Pharmodynamie et de Therapie OM -	NCE	NCE	NCE	NCE		X(3)		
255. Biochemical Pharmacology		X(3)				X(3)		
256. British Journal of Pharmacology		X(3)				X(3)		
257. Molecular Pharmacology	X(4)					X(3)		
258. Pharmacological Review		X(3)				X(3)		
259. Psychopharmacology		X(3)				X(3)		
260. Toxicology and Applied Pharmacology		X(3)				X(3)		
261. Nannyn-Schmiedebergs Archives of Pharmacol.		X(3)				X(3)		
262. Pharmacology Bioechmistry and Behavior								
263. Journal of Pharmacology & Experimental Therapeut.			X(3)			X(3)		

Names of Biomedical Science Journals	Research Shell Classification				Narin/Pinski Research Level Classification			
	S_1	S_2	S_3	S_4	L_4	L_3	L_2	L_1
264. Journal of Pharmacy and Pharmacology		X(3)				X(3)		
265. European Journal of Pharmacology		X(3)				X(3)		
266. Clinical Pharmacology and Therapeutics			X(2)				X(2)	
267. Journal of Antibiotics OM-	ED	ED	ED	ED	X(4)			
PHARMACY								
268. Chemical and Pharmaceutical Bulletin		X(3)				X(3)		
269. Journal of Medicinal Chem.		X(3)				X(3)		
270. Journal of Pharmaceutical Sciences		X(3)				X(3)		
271. American Journal of Hospital Pharmacy				X(1)				X(1)
272. Yakugaku Zasshi - J. Pharmaceutical *Soc.* Jap.		X(3)				X(3)		
PEDIATRICS								
273. Acta Paediatrica Scandinavica		X(3)					X(2)	
274. Amer. J. of Diseases of Children			X(2)				X(2)	
275. Arch. of Diseases in Childhood			X(2)				X(2)	
276. Clinical Pediatrics				X(1)				X(1)
277. Pediatric Research		X(3)				X(3)		
278. Pediatrics			X(2)				X(2)	
279. Pediatric Clinic of North America				X(1)				
280. Journal of Pediatric Surg.				X(1)				X(1)

Names of Biomedical Science Journals	Research Shell Classification				Narin/Pinski Research Level Classification			
	S_1	S_2	S_3	S_4	L_4	L_3	L_2	L_1
281. Journal of Pediatrics			X(2)				X(2)	
282. Biological Neonate OM -	ED	ED	ED	ED		X		
PHYSIOLOGY								
283. Acta Physiologica Scandinavica	X(4)				X(4)			
284. American Journal of Physiology	X(4)				X(4)			
285. Annual Reviews of Physiology	X(4)				X(4)			
286. Canadian Journal of Physiology	X(4)				X(4)			
287. Journal of Applied Physiology		X(3)			X(4)			
288. Journal of General Physiology	X(4)				X(4)			
289. Journal of Physiology	X(4)				X(4)			
290. Quarterly Journal of Physiology	X(4)				X(4)			
291. Physiological Reviews	X(4)				X(4)			
292. Pflugers Archiv-European Journal of Physiology	X(4)				X(4)			
293. HSZ Physiology Chem.	X(4)				X(4)			
PSYCHIATRY								
294. Acta Psychiatrica Scandinavica			X(2)				X(2)	
295. American Journal of Orthopsychiatry				X(1)				X(1)
296. Archives of Neurological Psychiatry			X(2)					X(1)
297. British Journal of Psychiatry			X(2)					X(1)

Names of Biomedical Science Journals	Research Shell Classification				Narin/Pinski Research Level Classification			
	S_1	S_2	S_3	S_4	L_4	L_3	L_2	L_1
298. Journal of Nervous and Mental Diseases			X(2)					X(1)
299. Psychosomatic Medicine			X(2)				X(2)	
300. International Journal of Psychiatry				X(1)				X(1)
301. American Journal of Psychiatry			X(2)					X(1)
302. Biological Psychiatry		X(3)					X(2)	
303. Diseases of the Nervous System OM -	ED	ED	ED	ED				X(1)
PARASITOLOGY								
304. Journal of Parasitology	X(4)				X(4)			
305. Exp. Parasitology	X(4)				X(4)			
306. Parasitology	X(4)				X(4)			
307. Int. J. Parasitology	X(4)				X(4)			
308. Journal of Protozoology OM -	NCE	NCE	NCE	NCE	X(4)			
RESPIRATORY SYSTEM								
309. American Reviews of Respiratory Diseases			X(2)				X(2)	
310. Respiration				X(1)				X(1)
311. Respiratory Physiology	X(4)				X(4)			
312. Scandinavian J. of Respiratory Diseases			X(2)				X(2)	
313. Thorax								
RADIOLOGY AND NUCLEAR MEDICINE								
314. Acta Radiological			X(2)					X(1)

Names of Biomedical Science Journals	Research Shell Classification				Narin/Pinski Research Level Classification			
	S_1	S_2	S_3	S_4	L_4	L_3	L_2	L_1
315. British Journal of Radiology			X(2)				X(2)	
316. Int. Journal of Radiation Biology	X(4)				X(4)			
317. Int. Journal of Radiation Oncology OM -	ED	ED	ED	ED	--	--	--	--
318. Journal of Nuclear Medicine			X(2)				X(2)	
319. Radiology			X(2)					X(1)
320. Radiation Research	X(4)				X(4)			
321. American Journal of Roentgenology				X(1)				X(1)
322. Acta Radiologica-Oncology Radiation Physics & Bio.	X(4)							X(1)
323. International J. of App. Radiation and Isotopes OM -	ED	ED	ED	ED				
SURGERY								
324. American Journal of Surgery				X(1)				X(1)
325. Annals of Surgery				X(1)				X(1)
326. British Journal of Surgery				X(1)				X(1)
327. Archives of Surgery				X(1)				X(1)
328. Acta Chisurgica Scandinavica				NCE			X(2)	
329. Surgery				X(1)				X(1)
330. Surgery Gynecology & Obstetrics				X(1)				X(1)
331. Surgical Clinica of North America				X(1)				X(1)

Names of Biomedical Science Journals	Research Shell Classification				Narin/Pinski Research Level Classification			
	S_1	S_2	S_3	S_4	L_4	L_3	L_2	L_1
332. Surgical Forum		X(3)						
333. Journal of Thoracic and Cardiov. Surgery				X(1)				
UROLOGY								
334. Journal of Urology				X(1)				X(1)
335. Investigative Urology		X(3)					X(2)	
336. Urological Clinics of North America				X(1)				X(1)
337. Scandinavian Journal of Urology & Nephrology OM -	ED	ED	ED	ED				
338. British Journal of Urology				X(1)				X(1)
339. Urology				X(1)				X(1)
VIROLOGY								
340. Acta Virologica	X(4)				X(4)			
341. J. Gen. Virology	X(4)				X(4)			
342. J. Virology	X(4)				X(4)			
343. Virology	X(4)				X(4)			
MICROSCOPY								
344. J. Elect. Microscopy	X(4)				X(4)			
345. J. Microscopic Organism	X(4)				X(4)			
GENERAL								
346. Nature	X(4)				X(4)			
347. Nature -- Biology	X(4)				X(4)			
348. Science	X(4)				X(4)			
349. Proceeding National Acad. Science USA	X(4)				X(4)			

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VITA

Daniel Newton Obaka was born on September 22, 1945, in Dekina, Nigeria, where he received his elementary and high school education. In 1972, he was awarded the Bachelor of Science degree from the Ahmadu Bello University, Zaria, Nigeria with double majors in Mathematics and Physics. He went to teach in high school until 1974 when he joined the University Library of the Ahmadu Bello University, Zaria as Graduate-Assistant-Librarian-in-Training. While working there, he attended the Library School at the University and received his Masters in Library Science in 1979. He joined as the head of Medical Library of the Ahmadu Bello University Medical School, Zaria, in 1977.

He remained at the Medical Library of the Ahmadu Bello University Medical School until 1979, at which time he was awarded scholarship and study fellowship to undertake a study leading to Doctor of Philosophy in Library and Information Science at Indiana University. His inside major was Medical Librarianship/Information Science and inside minors were International Librarianship, Education for Librarianship and Special Librarianship. His outside minor was History and Philosophy of Science.

Mr. Obaka received his Doctor of Philosophy degree in 1983 from Indiana University.

He works at the Medical School of Ahmadu Bello University, Nigeria as both the Medical Librarian and head of Medical Libraries.