3.1 Genesis & Development

Evolution of the concept informetrics can be traced back to the introduction of the term 'Statistical bibliography' [1] by Hulme in 1923 to denote the application of quantitative methods to library and bibliographic works. After Hulme, Gosnell used the term in his thesis to 'emphasise on the quantitative aspect than qualitative' [2]. Raisig also claimed that there was potential utility of statistical bibliography as a method of analysing information needs [3].

Statistical bibliography originated from two terms, statistics and bibliography. 'Statistics' is derived from the word 'status' meaning, state, position, standing. Websters dictionary defines it as "facts or data of a numerical kind, assembled, classified and tabulated so as to present information about a subject" [4]. Bibliography is derived from 'biblion' meaning 'book' and 'graphos' meaning 'to write'. Webster's dictionary defines it as "a list of authors writings or the literature dealing with a certain subject or author" [4]. Hulme defines bibliography as the "science of organization of knowledge" [1]. Statistics and bibliography combined to form statistical
bibliography, which generally denotes quantitative methods in Library Science.

In 1948 S.R. Ranganathan suggested the use of 'librametry' to refer to 'quantitative research in libraries' [5]. He also recommended the application of statistical and mathematical techniques in Indian libraries to improve their day to day activities and services. In 1969, Pritchard used the term 'bibliometrics' instead of statistical bibliography to denote the "application of mathematical and statistical methods to books and other media of communication" [6]. He considered statistical bibliography as a misnomer as it may be misinterpreted as bibliography of statistics. Fairthorne described bibliometrics as the "quantitative treatment of properties of recorded discourse and behaviour appertaining to it" [7]. The term bibliometrics was accepted widely instead of statistical bibliography after the publication of Pritchard's paper in 1970 [8]. Bibliometrics consists of two terms 'biblio' meaning book and 'metrics' meaning science of meter i.e. measurement. Bibliometric studies are limited to recorded information. Pritchard defines it as follows:

"The definition and purpose of bibliometrics is to shed light on the process of written communication and of the nature and course of a discipline (in so far as this is displayed through written communication) by means of
counting and analysing the various facets of written communication).

The British standard glossary of documentation terms explained bibliometrics "as the study of the use of documents and patterns of publication in which the mathematical and statistical methods have been applied" [9]. Potter defines it as "the study and measurement of the publication patterns of all forms of written communication and their authors" [10]. Sengupta describes it as "organization, classification and quantitative evaluation of publication patterns of all macro and micro communication along with their authorships by mathematical and statistical calculus" [11].

According to Hertzel, "Bibliometrics the science of recorded discourse - which uses specific methodologies, mathematical and scientific, in its research - is a controlled study of communication. It is the body of a literature, a bibliography quantitatively or numerically or statistically analysed - a statistical bibliography; a bibliography in which measurements are used to document and explain the regularity of communication phenomenon" [12].

Bibliometric studies fall in two broad groups - descriptive (productivity count) and evaluative (literature usage count). Descriptive studies may concern geographic, time or discipline. Evaluative cover references or citations. According to Nicholas and Ritchie "Bibliometrics
provide information about the structure of knowledge and how it is communicated" [13]. They divided the bibliometric studies into two groups those describing the characteristics or features of the literature (descriptive) and those examining relationships formed between component of a literature (behavioral). Evaluative studies use the references to literature used by research workers in a field. The scope of bibliometrics include studying the relationship within a literature or describing a literature, focusing on consistent patterns involving authors, monographs, journals or subject.

Bibliometrics has grown into a vast subject involving researchers from different branches of human knowledge. Thus synonymous terms like 'Scientometrics' coined by Russians to application of statistical methods to science emerged. FID developed the term 'informetrics' to mean measure and quantify information. It also established a committee on informetrics. Brookes, at the international conference on bibliometrics and informetrics held at Ontario in 1989, suggested that 'Informetrics' is the appropriate term to cover all the "quantitative studies related to information science" [14]. Thus it is seen that informetrics evolved from earlier terms like statistical bibliography, librametry, bibliometrics and scientometrics. Informetrics is "the study of quantitative aspect of information in any form, not just records or
bibliographies, and in any social group, not just scientists. Thus it looks at the quantitative aspects of informal or spoken communication, as well as recorded, and of information needs and uses of the disadvantaged, not just the intellectual elite. It can incorporate, utilise and extend the many studies of measurement of information that lie outside the boundaries of both bibliometrics and scientometrics" [15].

As the term bibliometrics is expanded into informetrics, the definitions, descriptions and regularities also applies to informetrics. Informetrics is defined as "use and development of a variety of measures to study and analyse several properties of information in general and documents in particular" [16]. According to Lancaster, "Informetrics covers all quantitative analyses of information transfer, whether or not they involve the published literature" [17]. Scientometrics, the term used by Russians to quantitative studies of science is considered a term related to informetrics. "Scientometrics is the study of quantitative aspects of science as a discipline or economic activity. It is part of the sociology of science and has application to science policy-making. It involves quantitative studies of scientific activities, including among others, publication, and so
overlaps bibliometrics to some extent" [15]. From the definition the scope of scientometrics is limited to studies of science, whereas the informetrics studies are spread over all fields of knowledge. Because of the wider scope of informetrics a series of international conferences in the topic which discuss the emerging methods and applications for research in this field are organised. According to Lancaster, the subject has grown from simple data analysis to well defined subject involving applied statistics, modelling, simulation, cluster analysis, study of citation network etc.

3.2 Literature Review

One of the first papers based on significant statistical data was by Cole and Eales in 1917 [18]. Statistical analysis of literature on comparative anatomy is done using publication counts and graphic illustrations in the paper. This paper came out before the subject bibliometrics was formed as a separate discipline or even before formation of the concept statistical bibliography. The study by Hulme in 1923 is considered as the first analytical account on growth of literature. In this, the productivity of scientific literature was critically evaluated for a period of time and came to the conclusion that the decline and rise of scientific literature are influenced by population change, political and economic movements. Another importance of the paper was that for the
first time the term statistical bibliography was used in scientific literature in 1923.

Later in 1926, scientific productivity formula which later became known as Lotka's law was published [19]. Gross and Gross wrote a paper based on the studies of references in "Journal of American Chemical Society" [20]. From their study it was decided to make use of a number of specific periodicals needed for a college library. This was the beginning of the first recorded study of citation analysis and later remained as a model for further studies.

Bradford, in 1934, published a paper on scattering which later came to be known as Bradford's law of scattering, the first important law to appear in informetrics research [21]. Bradford, while investigating on 300 abstracting and indexing journals stumbled upon the fact that "out of 750,000 articles, only 250,000 are dealt with and the remaining 500,000 are missed". This led to further investigation by using a bibliography on applied Geophysics (1928-1931) and Lubrication (1931-1932) compiled by Lancaster Jones. From this, Bradford established a hypothesis that "to a considerable extent, the references are scattered throughout all periodicals with a frequency, approximately related inversely to the scope" [22], Bradford's law is discussed in detail in his book "Documentation" published in 1948.
The next contribution to bibliometrics was by Zipf, G.K. when he put forward the relation between rank and frequency of word usage in his book published in 1935 [23]. This later came to be known as Zipf’s law of word frequency. By using M.L. Hanley’s "Index of words for James Joyce's Ulysses", Zipf studied the frequency and that lead to the formation of law.

Fussler, in a classic paper in 2 parts discussed "the importance of literature of various subject fields to research in Chemistry and Physics" and the temporal span of the literature, the principal forms of the literature, the national origins of the literature used in the United States, and some attention is devoted to the more important serial titles" [24].

Garfield, in 1955 presented the concept "Impact factor" [25]. The influence of a journal or an article during a specific period was termed impact factor. Garfield further stated that journals can be ranked by frequency and by impact of citations for science policy studies. "Impact is a measure of relationship between citations and articles published" [26]. Another method to measure journals or articles cited is by 'Immediacy index' which indicates how quickly they are cited. These values are published in Journal Citation Reports. Narin used measure of 'influence' of a journal [27] by calculating citation ratio between two journals i.e. the extent to which one cites the other.

A paper on epidemic theory, a technique explaining the transmission of ideas by means of literature was published by Goffman and Newill in 1964 [31]. In this, an 'infectious disease epidemic' is compared to 'intellectual epidemic'. The purpose of this was to help to describe the publication activity within a given discipline to determine the necessity for an information retrieval system. This model depends on the rate of change over time of 3 groups - infectives, susceptibles and removals. Susceptibles are those who have not yet contributed paper to literature but may do so in future. Infectives are those who have contributed earlier and are no longer contributing articles. Removals are those who are neither infective nor susceptibles. This can be applied to clusters of papers - an original paper being infective and papers which cite original - susceptible.

The next important paper in chronological order is by Pritchard in 1969 in which the term 'bibliometrics' was first suggested instead of statistical bibliography [6]. Small, describes relation between two documents by a new kind of coupling - "co-citation" which is "the frequency
with which two items of earlier literature are cited together by later literature" [32].

After 1970, a proliferation of papers appeared on various methods and applications. Earlier papers were mainly on theoretical and empirical aspects. Theoretical papers accepted mathematical formula rather than empirical data to study various distributions. Vickery examined Bradford's analysis and found there is difference in verbal and graphical expressions of the law [33]. Kendall took into account the references in operational research and came across a relation between Bradford and Zipf distribution [34]. Leimkuhler analysed Bradford's law and suggested that the 'law of scattering' predicts the number of references for a given portion of journals while the 'distribution' gives emphasis on the number of journals required to obtain a given portion of reference [35]. Brookes criticised the above work and opined that it is theoretically possible but practically difficult to apply [36]. Yablončky examined in detail the bibliometric and scientometric core-scatter distributions and concluded that there exist a close similarity [37] between these two parameters. According to Haitun [38] Zipf's distribution is basic to all the other distributions. Bookstein suggests that the three informetric distributions as unified models [39, 40, 41]. Egghe gives more importance to the studies on the classical bibliometric laws and the similarity and difference between them [42] while Rousseau discuss the
relation between informetric laws and how they differ [43] in certain vital aspects.

Literature on empirical studies are based on two types of studies - probability (prediction) and evaluation. Some important papers of similar nature are by Pratt [44], Drott [45], Lawani [46], Goffman and Morris [47], Brookes [48] and Egghe [49].

A new method i.e. explicativity developed by Good I.J. is explained by Tague [66] in her paper as a new method to test models to data. At present models suggested by Brookes and Bookstein, Ravichandra Rao and Tague have gained wider applications in information studies than any other models.

After the starting of journal 'Scientometrics' in 1977 edited by Tibor Braun, many papers related to informetrics are published in this journal. A number of review papers on Informetrics which give an overview of the subject and explain the key concepts form a major part. Important among them are those of Broadus, [67] Hertzel [12] Bensman, [68] Lawani [69], Rao [70], Ikpaahindi [71] Narin [27] Zunde [72] White and Mccain [73]. Bibliographies on informetrics were compiled such as by Pritchard and Wittig [74] Hjerppe [75] Schubert [76] and Sellen [77].

By the advancement of technology, informetric studies are conducted using data collected by online search. Papers by Oppenheim [78], Persson [79] Hibbs [80] Lancaster and Lee [81], Stefaniak [82] deal with online studies. This method might get more practical applications in future though it has some limitations at present, such as coverage of database, data retrieval method etc.

3.3 Informetric Laws

In many fields researchers find some regularities while counting events or tabulating size of things. These are
often known as models, measures or laws and are derived from empirical observations or statistical inferences. Informetrics as such deal with the study of library and information dissemination processes by using quantitative treatment of the properties and behaviour of knowledge. In such studies some theoretical formulations and generally valid laws are discovered. These laws may loose their validity or change when there is an alteration in the existing environment. In informetrics this type of large scale changes are unlikely to take place. Therefore these laws remain valid eventhough some new changes are suggested by later researchers. The three classic laws in informetrics are Lotka's law of Scientific productivity (based on Author productivity in terms of papers published), Bradford's law of scattering (based on distribution of articles over various journals) and law of word occurrence (ranking of word frequency in a text). These laws and several new models based on these are discussed below.

3.3.1 **Lotka's law**

Lotka in 1926 formulated the law of frequency distribution of authors in relation to number of articles produced. This became known as the inverse square law of scientific productivity. It states that the relation between frequency distribution of 'y' persons making 'x' contributions in $x^ny = c$. The value of constant when $n = 2$
was then calculated. Lotka explained the phenomenon as follows:

"In the cases examined, it is found that the number of persons making 2 contributions is about one fourth of making one, the number making 3 contributions is about one-ninth etc the number making n contribution is about \( \frac{1}{n^2} \) of those making one, and the proportion of all contributions, that make a single contribution is about 60 per cent" [19].

Lotka studied counts of chemists, and their publications based on data from Chemical Abstracts and Auerbach's bibliography on Physics. The law was termed Lotka's law by 1949 and the applicability to other disciplines was tested only by 1973. Murphy studied the applicability in humanities and found it was fit to this field [83], Voos, in 1974 measured productivity of authors in the field of information science and found that "the relationship in this field is \( \frac{1}{n^{3.5}} \) instead of Lotka's \( \frac{1}{n^2} \) [59]. In 1974 Schorr, applied the law to library science and showed that Lotka's law does not apply to the field of library science. In 1975 Schorr studied map librarianship and concluded that the law fits in this field. But Coile showed that Schorr's calculation was wrong as the law does not fit to map librarianship [84].

Pao, states that several studies have assumed the inverse square relation as the basis for testing, and
others derived the value of constant 'c' from the percentage of single paper contributors which cannot be traced back to Lotka's assumptions. "Therefore, a uniform method should be agreed upon by those attempting a test. Comparison and generalisation on author productivity may be possible only if compatible data are available and results are significant" [85].

There have been many analytical approaches different from Lotka's law for scientific productivity. Narin, concluded that "scientific talent is highly concentrated in a limited number of individuals" [27]. Dennis, found a close correlation between quantity of scientific publication and achievement of eminence. Price, concluded that the number of elite in science is small compared to total number of scientists. According to Price an elite mean an eminent scientist producing scholarly writing. Bookstein, suggested a theoretical model which is a generalised version of Lotka's law [39], \( f(x) = \frac{k}{x^\alpha} \) where \( k \) and \( \alpha \) are constants. According to this, the number of authors with \( x \) papers is proportional to \( 1/x^\alpha \).

Some recent studies on author productivity by Pao, Nicholls and Griffith used the version of Lotka's law by Bookstein, in their studies and estimated the values of \( n \) rather than using \( n = 2 \). They counted authors and suggested a goodness-of-fit test for the model. Nicholls showed that
the generalised version is "surprisingly well fitting and stable" [86] and Pao concluded "overwhelming conformity" [87] to this model.

Price suggested that "Half of the scientific papers are contributed by the square root of the total number of scientific authors" [88]. This became known as Price's square root law and was proved to be invalid both theoretically and empirically [89] by further studies conducted by Nicholls.

While applying Lotka's law, the problem of crediting authorship to multiauthored paper occurs. Originally Lotka counted only first author in multiauthored paper. Bookstein discusses this in a paper and concluded that "if Lotka's law holds for one accounting method, it will hold for any other one in which the change in the typical amount of credit given to authors per paper may vary from author to author but does not depend strongly on how much the authors published. If this is true, the investigator can give any reasonable system of assigning credit to authors while studying author productivity [90].

In author productivity studies it is seen that the number of single paper producers are more. This aspect has been given a thorough scrutiny by many others. It is shown that authors who are more productive are having more collaborative studies than single paper producers. Because
of the transdisciplinary nature of research topics, there is more scope for multiauthored paper than single authored paper. Jointly authored papers are cited more times than a single authored paper. Lawani has shown that "citation rate and quality of paper (as judged by a form of peer review) both correlate positively with number of authors per paper" [91]. In addition to collaboration, individual productivity is affected by working environment, motivation, reward system etc.

3.3.2 Bradford's Law

This law is the most prominent informetric law as it is applied to the control of literature. Bradford discovered the scattering phenomenon while studying the extent to which literature in a discipline is scattered over a range of journals. This was published in his classic article in 1934 [21]. Earlier, he was working on the necessity for standard bibliographical methods to avoid duplication and waste of time, money and to give better information service. While studying 300 abstracting and indexing journals duplication and omission of articles were found. This finding led to further investigation of two bibliographies on Applied Geophysics and Lubrication. For both subjects, tables giving number of journals producing corresponding number of articles were listed and then arranged them in the decreasing order of productivity. The list was found to have three zones each having the same
number of references. The number of journals in one zone when divided by number of journals in the preceding zone was found to be a constant which is known as Bradford multiplier. In the data studied it was approximately 5. Using the data Bradford constructed two graphs. One plotting the logarithm of cumulated number of journals against cumulated number of articles. He observed that the later part of the curve was close to a straight line and observed that "the aggregate of references in a given subject, apart from those produced by the first group of large producers, is proportional to the logarithm of number of sources concerned when these are arranged in the order of productivity" [21]. Based on this observation another graph was constructed to develop an algebraic relation for the straight portion of curve. From this the law was originated which states that:

"If scientific journals are arranged in the order of decreasing productivity of articles on a subject, they may be divided into a nucleus of periodicals more particularly devoted to the subject and several groups of zones containing the same number of articles as the nucleus, when the number of periodicals in the nucleus and succeeding zones will be as 1:n:n^2 [21].

Bradford's law received wide attention after the publication of his book in 1948 in which the law is discussed in detail. In the book he also used the same data
as in the first paper in which the law was presented. Since then the law had been used in various studies and mathematically is expressed as:

\[ F(x) = a + b \log x \]

where \( F(x) \) is the cumulated number of references contained in first \( x \) most productive journals, 'a' and 'b' are constants.

Bibliographic studies in a number of fields confirm that the dispersion of articles in a set of journals conform to the statistical distribution of the type described by Bradford. But arriving at a mathematical expression for this distribution led to many articles on the topic.

In 1948 Vickery published a paper based on analyses of 1600 periodical references. He found that Bradford's law was not in total agreement with his algebraic expression. Vickery concluded that the relation which Bradford discovered only "fits the upper portion of the observed curve" [33]. Cole, also took a new look at reference scattering in which he plotted the cumulative fraction of references against the logarithm of the cumulative fraction of titles and he named the slope obtained as "reference-scattering coefficient" [92].

Leimkuhler was the first to give a theoretical expression to the scatter of journals, which was found to
be the inverse function of the Bradford distribution. Leimkuhler's Bradford distribution is given as

\[ F(x) = \frac{\ln(I + Bx)}{\ln(I - Bx)} \]

where \( x \) denotes the fraction of documents in a collection which are most productive, \( F(x) \) denotes the proportion of total productivity contained in the fraction \( x \). The parameter \( B \) is related to the subject and completeness of collection [35].

Brookes gave a simplified form of this formulation as this required much tedious computation for practical use. The new form is \( B(r) = a + k \log r \), where \( B(r) \) represent total number of articles published in journals upto rank \( r \), \( a \) and \( k \) are constants. This became the widely used formulation of Bradford's law [93].

Wilkinson in 1972 suggested that the formula provided by Brookes and Leimkuhler did not describe the same phenomenon. The error was due to Bradford's graphical representation of his Applied Geophysics data and the verbal expression of the law. Wilkinson observed that Leimkuhler derived his distribution from Bradford's verbal representation and Brookes from the graphical representation [61]. In comparative tests Brookes formulation conformed more closely to empirical data.

Naranan modelled the dynamic process of accumulation of articles in journals in terms of a power law distribution
assuming that number of articles and journals grow exponentially [94].

This assumption was not found valid as Bradford's law fits even when articles and journals do not grow exponentially. Brookes suggested that Naranan's analysis is more valid for Lotka's law than for Bradford's law.

Lawani, in a study of literature of agriculture found the distribution conformed to Bradford's law. The curve obtained was linear with a Groos droop [95] for journals of lowest rank. This was a point of controversy. Brookes viewed that this was due to the incomplete bibliography. But O'Neill concluded that the Groos droop is not due to the incomplete bibliography but is a part of Bradford distribution [96].

Goffman and Morris applied Bradford's law to a study on library acquisitions. They stated that "Bradford's law should apply to the use of periodicals in a library as well as to the dispersion of articles among journals" [47]. They showed that the distribution of both circulating periodicals and their users obey the law. Hence the smallest core of journals which must belong to the library's collection can be defined. This core should consist of a minimal nucleii of periodicals circulating in the library plus the minimal nucleii of journals devoted to the subjects of most interest to the library's nucleus of
users. As the funds allow successive zones of periodical corresponding to circulation and user interest can be added. As a result the library collection can be maintained in an orderly fashion and viable state thus providing its patrons with the most potentially usable material for the funds at disposal.

Fasler, in a comment on the above wrote that it was the most promising method but with a warning that "before it is possible to discontinue a journal subscription, it is necessary to make sure that such action will not cause great inconvenience [97]. In 1975 pope claimed that "the area in which Bradford's distribution has the greatest potential is in collection development" [98].

In 1977 Brookes did a complete re-evaluation of the law and stated that "the analysis of Bradford's law has hitherto been applied to theoretical models which are too static, too deterministic and too physical. All Bradford data are derived by observing the activities of a set of sources over some appropriate period of time and by noting these activities, as measured in terms of the numbers of items each source accounts for in that time. Thus the Bradford's law is concerned with:

1) a finite set of active sources whose activities are made to manifest with the generation or consumption of a specified type of item.
2) observation of those activities over a specific sampling period.

3) items of some homogenous kind which are discrete and countable [50].

Statistical distributions depend on relationships between the number of active sources, the range and intensity of their activities, and the period of observation which provides the sample data. All Bradford distributions are samples of some ongoing activity but all too often, the sample data have been regarded as constituting a total population. Brookes was a major writer on Bradford's law. In one paper he states that a new statistical theory based on both Bradford and Zipf's laws together "provide the most convenient analytical instrument for the exploration of social science data" [48].

A general formulation of the law is given by Asai [99] in which five types of laws formulated by earlier papers are combined and made into one. This paper provides a non-linear regression technique for estimating the slope, intercept and "shift in a straight line to log rank" of the Bradford curve. Chen and Leimkuhler [100] noted that Asai's formulation treats rank as a continuous variable without gaps which lessens the realism of the model. They suggest the 'index approach' to rectify this. They also identify two parameters that affect the shape of Bradford
curve (non-linear) in least productive and most productive zones. Drott and Griffith have shown that the linear slope of Bradford curve is related to the number of articles plotted and the intercepts are related to the number of journals [101].

Karmeshu et al derives a rationale for Bradford's law based on random subdivision of papers over the field of journals and on individual scientific productivity [102]. Bradford's law and other statistical laws are explained by Price as cumulative Advantage Distribution of the success-breeds-success type [51]. He obtains a relation of the form \( F(n) = (m+1) B(m+2) \) when \( n \) is number of successes \( m \) is a constant and \( B \) a Beta function.

A few examples are:

a) A journal which has been used is more likely to be used again.

b) An Article in a journal cited many times is more likely to be cited again.

c) An author of many papers is more likely to publish again than one who is less prolific.

Ravichandra Rao also supports this but shows that the negative binominal distribution describes this phenomenon better than cumulative advantage distribution [103]. In statistics this is generally described by a hyperbolic
distribution function known as Yule distribution. This is shown to vary with sample size. Yule characteristic

\[
1 + (\text{sample variance} - \text{mean}/\text{mean})^2
\]

\[
k = \frac{1}{\text{Number of Classes}}
\]

Garfield advances a measure of concentration of articles in journals [104]. This Bradford phenomenon shows a gradual concentration of articles to a few core journals in a subject. This is due to the explosion of literature and number of journals. Bradfords law enables to do a literature search among numerous journals and saves the users from 'documentary chaos'.

Maia and Maia show that there is no ambiguity in Bradford's theory of distribution [105]. It is also verified that in the Bradford's experiment the verbal and graphical expressions are in agreement showing that there is no ambiguity. Earlier, Wilkinson also studied the ambiguity of Bradford's law and concluded that a documentation researcher has no means to decide which formulation (verbal or graphical) should be used. O'Connoor and Voos also examine the relation between theory and empirical laws [106]. Another paper by Drott also studies the theoretical and empirical development of Bradford's law [107]. But Bookstein in a recent paper discussed the various informetric laws as the different versions of a single regularity and explored the
consequences of demanding that informetric laws are resilient to ambiguity [90].

Burrell studied the Bradford phenomenon and opines a stochastic process termed 'Waring process' which conforms to the general features of Bradford's law [108]. In another work he examined the dynamic nature of bibliometric processes by analysing a bibliography compiled over an extending period of time using Bradford and Leimkuhler curves. The theoretical and practical importance of stochastic processes to model these systems are also given [109].

Recently, Aparna Basu attempted to find a theoretical foundation for Bradford's law and suggests a modified log-linear two parameter model to explain journal productivity [110].

3.3.3 Zipf's Law

Zipf, explained this law in 1935 based on the frequency of occurrence of words in a text. It states that "if the number of words occurring once in a given sample is taken as x, the number of different words occurring twice, three times, four times, 'n' times in the sample is respectively \[ \frac{1}{2^2} \quad \frac{1}{3^2} \quad \frac{1}{4^2} \quad \cdots \cdots \cdots \quad \frac{1}{n^2} \]

of x". From this zipf developed a formula \[ ab^{2} = k \]
where a is the number of words occurring b times.
Zipf explained the law as a consequence of a general "principle of least effort" in his book published in 1949 [111]. Zipf applied his principle to study Hanley's Index of words for James Joyce's Ulysses' and found a clear-cut correlation between rank \( r \) and frequency \( f \) of word, which is represented as \( rf = C \). When the law is applied exactly, a hyperbola is obtained while plotting the frequencies against rank.

Many studies were conducted on Zipf's law. Wyllys, expressed it as "one of the most puzzling phenomenon in bibliometrics" [112]. Simon, in a paper observed the fitness of the Yule distribution to a number of empirical data including word frequency [113]. Hill, wrote a group of papers on Zipf's law. Mandelbrot, published several observations on the generalizations of Zipf's law. In 1975 Wyllys presented a paper at the 38th Annual meeting of ASIS, which gives that "inclined towards mysticism, Zipf not only leaped to the conclusion that the true slope of rank frequency curve was \(-1\), but also claimed that this regular slope resulted from some fundamental force of nature" [114].

Hubert, reviewed the law and its development in later work. Fedorowicz applied the distribution of indexing terms in inverted files of bibliographic databases using Zipf and other models [115, 116]. In another paper by Tague and Nicholls, attempts in relating the law to file
The simple Zipf size-frequency distribution for tokens is presented as $g_x = a/x^b$ where $g_x$ is the number of type with $x$ tokens, $a$ is the number of types with single token and $b$ dispersion of token over types.

Zipf's law, like other informetric laws can be related to the forms of description traditional in statistics like cumulative distribution function. It is also observed that Pareto's law in economics which relates the income and number of people are a variant of Zipf's law.

3.3.4 Informetric distributions Lotka-Bradford-Zipf relation

Number of studies have been made regarding the theoretical and practical implications of the informetric laws. These led to the study of relationship between the different laws. Earlier relation between Bradford and Zipf's law were explained by researchers like Kendall, that these two are almost equivalent. He supported the idea that Bradford distribution is really Zipfian and provided a more refined statistical explanation for the straight line observed by Bradford. Leimkuhler also agreed with Kendall's theory that the two laws were essentially two different angles of looking at the same thing. Brookes studied the Bradford-Zipf phenomenon and says that "the near identify of Zipf's and Bradfords laws are not immediately obvious because, in practice, the most marked deviation of empirical data from the mathematical expectations of
Bradford's law are likely to occur among most productive journals of the nucleus" [36]. Journals also lack statistical unity as they are not issued at regular intervals and number of articles per issues also vary.

Garfield writes that "while each 'law' applies to a different specific phenomenon, they all tend to demonstrate one thing that a few (journals, scientists etc.) account for the many (articles, citations etc)" [104]. He relates the Pratta index which measure the degree of concentration of papers in a subject to Bradford's law. Many theories unifying the various statistical distributions are put forward. Garfield proposes a theory of 'concentration' which points out that for any field of science, articles are concentrated essentially within the same highly cited or multidisciplinary journals. Price proposed a unifying conceptual model for Bradford, Zipf, Lotka and other statistical laws by the theory of "cumulative advantage processes" which is based on success-breeds-success phenomenon [51]. Ravichandra Rao also supports this phenomenon in the case of use of documents.

All the informetric distributions are claimed to be essentially one by authors like Yablonsky [37], Bookstein [39, 40, 41]. Haitun [38] considered Zipf's as fundamental distribution. Brookes [48], argues that a new statistical theory based on Zipfian distribution is needed for applications to social sciences. He proposes the use of
Bradford and Zipf law together for analytical exploration of social science data. In another paper he says that both Bradford's and Zipf's are rank-frequency distributions. He also opines that there remains a theoretical gap yet to be bridged as long as there remains some aspects in bibliometrics beyond the reach of techniques dependent on analysis of frequency distribution.

A common functional relationship between the three laws are derived by Chen and Leimkuhler using the data from Kendall's study of bibliography of operational research [119]. They also propose a more useful formulation for the three laws.

Egghe gives an inventory of bibliometric laws and develops the 'criteria by which they are the same or different (eg. asymptotically)' [42]. The informetric distributions are described as 'variants of a single distribution' by Bookstein [40]. These provide rich and diverse issues and approaches for research in the field.

Research in the field using the laws have shown close similarity or even identity between the models underlying the empirical distributions. However since Bradford's law deals with journal studies and Lotka's law with author studies it is easy to see the literatures as different forms of the same mathematical phenomenon. The advantage of informetric distribution is their simplicity and
familiarity. But their use will depend on how well they assist in making decisions.

3.4 Citation Analysis

Informetric studies depend mainly on document units or written records of communication i.e. books, journals, articles, reports etc which form the objects of studies. As the physical documents are difficult to handle in large quantities, the "document representations" are considered for informetric studies. Currently bibliographies and databases or data from users are also used in the studies. These can be considered as secondary sources in informetric studies. The "document representations" are usually known as reference or citations. References are the acknowledgement one document gives to another while citations are acknowledgement one document receives from another. According to Weinstock "when a scientist or technologist publishes an article, he should refer to earlier articles which identify earlier researchers whose concepts, methods etc. were used by the author to develop his own article" [120].

Citation analysis is the most common technique which is considered an authentic tool for journal evaluation. It is based on the concept that articles citing an earlier work in scientific paper have much of their content in common. This has led to many studies including citation counts, impact factor, bibliographic coupling, co-citation
and obsolescence. Citation studies are valid for assessing the quality of research produced by individuals and institutions. It also correlates to the use of libraries by researchers. According to Garfield, Citation analysis "provides a number of interesting and useful insight into the network of journals that function as primary, formal communication medium of science" [121].

"Citation analysis means the analysis of the citations or references which form part of the articles in journals" [70]. Citations in journal indicate the connection between two documents - one which cites and the other which is cited, whereas citations in secondary periodicals does not imply any connection between documents. The main objective of citation analysis is to evaluate and interpret citations received by articles, authors, institutions and other aggregates of scientific activities. It is also useful in measuring communication links in sociology of science.

Barker in his thesis noted that there are two types of citation studies - (a) studies based on productivity in all or part of scientific literature and (b) those reflecting the use of all or part of the literature [122]. In the first type the source may be major abstracting or indexing journals, review journals, bibliographies or data bases. The second type of citation study is based on literature used by an author. Use of Bibliographies or abstracts are not considered true citation studies as they are compiled
for the purpose of use and do not represent actual use made by the users. True citation analysis deals with works cited as having actually been used.

Many arguments for and against the validity of citations by scientists are often given. Some such as too much self citation, negative citation, citing papers without seeing the original, citing to get favour of mighty and comfort lowly etc., are put forward against the validity of citation studies as actual use studies. But the honesty and integrity of the majority of the scientists who may not involve in such practices is to be given weight. In short, citations are the major tool for evaluating quality of research journals.

Many studies have found numerous reasons for citations to papers by the authors. Reasons for citations received by some highly cited papers given by Oppenheim and Renn [123] are:

1. Historical background
2. Description of other relevant work
3. Supplying information or data for comparison
4. Use of theoretical equation
5. Use of methodology
6. Theory or method not applicable or not the best one

Selection of source for citation studies are usually done by sampling as the collection of documents are usually
too large. One main source of data for citation studies are the science citation Index (SCI) published by Institute of Scientific Information (ISI) from 1963 onwards. These citation indexes give a list of documents that have been given as source journals covered by the index. The cited documents are ordered alphabetically by the author. Thus citation index forms a structured list of all citations in a given collection of documents. From 1973 ISI started publishing Journal Citation Reports (JCR) which are also useful in citation studies. This gives three lists-first a list of most frequently cited Journals for the period covered by JCR; second a list of journals in which they are cited (source journal listing); a third part shows the list of citing journals to the frequently cited journals (reference journal listing). The use of SCI for citation studies has its own merits and demerits. Some problems are due to self-citation, multiple authorship, homonym, errors in bibliography etc.

Initially the collection characteristics such as form (monograph, journal etc), type (articles, notes, news etc), subject (specific subject), set of authors, institutions etc are to be determined for citation studies. Then the objects of the study such as references, citations etc are to be selected. Other parameters like sources detail, level of aggregation, variables to be studied, period of study, methods, approach and purpose are to be determined
prior to the study. There is a large number of literature available on citation analysis. Some of the earlier work are those of Garfield [124] Tagliacozzo [125] and Hjerpe [126].

The first record of citation analysis is an article by Gross and Gross in 1927 in which the citation count is used to measure adequacy of a college library. Following this, a number of papers defining the importance and dispersion of the various segments of scientific literature came out. The publication of paper by Bradford analysing the importance of a small number of core journals for a specific subject became the basis for research afterwards. More attention was made on managing the rapidly growing scientific literature. Price made use of a number of literature counts to devise his outline of scientific enterprise. Citation counting began to attract more attention as a means of structuring scientific literature. Some of the important work which belong to this type are by Garfield [26], McCain and Bobick [128] and Brown [129].

Citation counts are often taken as a measure of the use of journals though the validity of this assumption is often criticised. Scales [130] in a study of the most used journals in National Lending Library compared it with highly cited journals listed in JCR. She concluded that there is no relation between actual use and citations. Brown suggested that ranking of periodicals in a discipline
also was made by selecting related secondary periodicals as source journals. Frequency of abstracts was taken to reflect the frequency of citation in a primary journal. This method also have limitations as the objective of the abstracting journal may be comprehensive to the subject coverage. Sengupta, in various studies suggest modifications like weightage formula [55], bibliometric parameters [131] and using annual review to collect source data [132] to eliminate the limitations in the use of raw citations. Recently informetric studies using data from on-line data bases are also suggested and attempted [133, 134]. The scope of studies based on citation analysis are vast. Some include ranking and evaluation, growth and decay, aging or obsolescence, clustering, bibliographic coupling, trend analysis etc. The most important and commonly used parameters among them are discussed below.

3.4.1 Ranking & Evaluation

Citation analysis is used commonly for preparing rank list of journals and evaluate journal in specific subjects. Earlier, most libraries relied on the judgement by the selection committee for deciding the journals for subscription. This usually depended on the utility in a local library. But for a library specialising in a discipline, utility alone may yield misleading data as the users turn out to be biased and the existing titles may be used repeatedly. Moreover if the funds are limited and the
demand for titles are more, then the librarian may have to adopt some criteria to find the most relevant titles. The most journal ranking studies use more than one criteria to evaluate the journals related to specific disciplines. Ranking journals using citation analysing combined with 'impact factor' study are very useful in the present context.

This type of citation studies help to identify core periodicals and formulate a need based acquisition policy in a scientific library. It also enables to assess the quality of research journals. Evaluative studies may have some limitations as this depends on the sample selected which may be from geographically and linguistically limited area. To overcome this, the number of sources can be increased covering almost all areas. The method of streamlining acquisition of journals in research libraries by finding core journals is economical and practical. Bradford's law or the other models derived from this are usually applied for journal ranking studies. Some studies are also based on data collected from users in one or a group of similar libraries.

Journal citation studies show that journals are strongly connected through the references in the articles they contain. Thus the core titles may be the highly connected journals. Garfield has done a number of journal citation studies on various disciplines [135]. The most
Informetric studies are on journal citations or their use. This is because the journals are a major communication channel for research in science and other fields.

Citation analysis also enables to study the number of papers produced by an author (author productivity or scientific productivity) by an institution (institutional productivity) by a country, (national productivity), the number of citations received by an author and, major areas of a subject where active research is going on etc. Measuring science by this method is helpful in determining the science policy of industrialised countries as well as less developed countries of the world.

Author productivity studies are done by using Lotka's law which is based on the assumption that frequency of authors producing papers is constant. Some of the studies by Pao [136], Nicholls (89) and Gupta [137] tests the applicability of lotka's law and its generalized form. Tests such as chi-square and K-S statistical tests were used to test the applicability of the law. Other investigations on scientific productivity led to the Prices theory of cumulative advantage distribution according to which if an individual (scientist, journal) becomes successful (publish yields an article) at the first attempt, the possibility of success at subsequent attempts increases. However, a failure does not diminish the probability of success on the next attempt. According to
Lotka's law is invariant under the impact of society on the pattern of scientific productivity.

Prices success-breeds-success phenomenon can also be explained by the 80/20 rule. According to this 80% of items (articles, number of publications, number of citations received etc.) are accounted for by 20% of sources (authors, journals etc.). In other words, 20% of journals receive 80% of citations or 20% authors contribute to 80% of literature. Egghe [139] shows that the 80/20 rule is much stronger if the underlying distribution is Lotka type.

3.4.2 Impact Factor (IF)

Citation frequency of a journal is not only a function of significance of the material it published but also the quantity of material it publishes. Thus the most cited journal may be the most productive journal also. In view of this relation between size and citation frequency, the size can be taken to assess the citation frequency. Thus the method of calculating "impact factor" or the influence of a journal article over a specific time was adopted in journal ranking studies. This method was first done by Garfield in the Journal Citation Report (JCR), a by product of Science Citation Index.

Journal Impact factor reflects the average citation rate per published article. It is calculated by dividing
the number of times a journal has been cited by the number of articles it has published during some specific period of time.

\[ \text{Number of citations received in year 3 by articles published in year 1 and year 2.} \]
\[ \text{IF} = \frac{X_1 + X_2}{Y_1 + Y_2} \]

where \( Y_1 \) and \( Y_2 \) are the number of papers published in a journal during two consecutive years, \( X_1 \) is the number of citations these papers receive by citation Index journals and \( X_2 \) is the number of citations these papers receive from the journal itself during consecutive year.

A new method of finding Discipline Impact Factor (DIF) formulated by Hirst [141] in which the citations made by a
few core journals are taken for computing impact factor. This gives an indication of the impact to the discipline. In this method, first a candidate journal of a specific discipline is selected from the most cited list of titles. The discipline influence score is computed by

\[
\text{DIS}_A = \frac{\text{No. of times } J_1 \text{ cited Journal } A}{\text{Total No. of times } J_1 \text{ cited all Journals}}
\]

where \( \text{DIS}_A \) is the discipline influence score of journal \( A \) in the candidate journal set. \( J_1 \) a member of Discipline Journal set and 'n' is total number of journals in Discipline journal set.

A study by He and Pao demonstrated this discipline specific journal selection and compared the results with that of expert evaluation, impact factor and total citation ranking [142]. User's preference was found more close to Discipline influence score than the other two methods.

Using the method of measuring impact factor, the output of a scientist, scientific organization or scientific agency can be analysed. Individual impact is a measure of impact of an individual's published output [143]. Institutional impact help to evaluate the output of research organisations in a country, various nations [144] or of a specific agency [145]. Opinions are divided on the evaluation of impact factor. Some people consider it as a misleading indicator of true impact [146]. Still some think that the ranking and
impact are relevant only in specific disciplines. In some subject, impact factor of journal varies from country to country [147]. Use of a normalised impact factor (NIF) is suggested by Sen and Kumar [148] to overcome differences among fields. This is given by adopting a 10-point weightage scale. The top ranking journal in each subject is given a weight of 10 and others are scaled down accordingly. This method is useful to study NIF at institutional or individual level.

Similar to impact factor, the 'immediacy index' and 'influence' are also suggested as measures to journal citation studies. Earlier, Garfield has shown that the newly published journals in a subject show high impact [26]. Immediacy index is a measure of how quickly the papers in journals are cited. It is calculated as follows:

\[
\text{Immediacy index} = \frac{\text{Number of citations received in year } X}{\text{Number of items published in year } X - \text{items published in Year } X}
\]

Tomer has shown that journals with high impact have high immediacy index [146].

Another measure of impact is the influence of a journal. This method is used by Narin [27] which involves complicated calculations which can be done by computer only. This involves finding citation ratio between two journals. From this data the influence weight can be calculated. The influence weight depends on the citation
relationship of a journals with all the other journals in a database. Influence weight multiplied by average number of references give the influence per publication, the value is then multiplied by number of papers to get the total influence. This calculation is more refined than impact factor as it takes into account the interrelationship of journal citations.

Impact factor and Immediacy index are ratios. Impact factor is the ratio of number of citations which a journal receives in the course of a given year to the number of citable items published by that journal within the two preceding calendar year. Immediacy Index is the ratio of number citations a journal receives in its most recent complete year of publication to the number of source items published during the same interval.

Ranking of journals based on informetric methods are found mostly to agree with the expert opinion. Some researchers are adopting new methods combined with citation studies to formulate list of journals more specific to different subjects. Sengupta has adopted three parameters to rerank periodicals in the field of biochemistry [131]. The parameters were (a) scientific interest of a paper based on a number of papers published (b) compactness of the information content in a scientific periodical (c) the scientific value of a paper in relation to compactness of presentation.
3.4.3 Aging or Obsolescence

Obsolescence is the process whereby the materials become no more useful or reliable. Aging or Obsolescence is also a measure of quality of a journal. It helps to assess the decline in use of a set of documents over time. Studies on aging are conducted in collection management aspects in specific libraries or in the journal references as the indicator of previously published work. The reasons attributed for aging of journals may be varied like changing scenario in scientific technique or extension of scientific knowledge etc. Rate of aging varies with discipline and is found as a characteristic of scientific and technical literature.

Aging studies are of two types-synchronous studies which use data of citations from a journal or a subject during a period to measure how old are the cited journals or compute 'median citation age'. In second type-diachronous studies, citation history of a document or subject from the beginning to the end of a period are studied and 'half-life', is calculated. It is seen that both types give different results.

According to Brookes the rate of obsolescence is related to the rate of growth of scientific literature and the number of contributions in the field [149]. If these measures are constant, then the rate of obsolescence also remains constant. Ravichandra Rao and Meera studied the
relation between growth and obsolescence and remarked that 
"faster the growth of literature then quicker the 
obsolescence as well as the half-life" [150]. Wallace 
hypothesized that "those journals that were most 
productive would have short active lives and as the 
journal productivity decreased, the average active lives of 
the articles would increase". According to Griffith "half 
the total citedness of a volume of an average scientific 
journal would be exhausted within five years after the 
publishation and more than 90% after 20 years" [151].

Obsolescence has been the concern of librarians for 
quite some time because of the overabundance of materials, 
lack of housing facility etc. By studying the aging, the 
'half life' or the time during which one half of the 
literature currently active originated can be calculated. 
The half life and median citation age shows how far back in 
time one must go to account for the age of one half of the 
bibliographic references published in a journal in a 
particular year. Price studied the percentage of references 
to works published in the most recent five year period 
known as Price's Index [152]. He attributed the citation of 
recent papers to "Immediacy effect" due to the citation of 
ephemeral papers at the research front.

Aging pattern shows the characteristic of source 
selected. In social sciences highly cited journals aged the 
literature more quickly than a randomly selected sample of
journals. Highly productive journals showed low median citation age and low productive showed high median citation age.

Line and Sandison [153] have criticized the study of aging using citation data or use data. They state that the growth of literature must be allowed for by calculating the density of the use for each title considered. Line calculated the density of use (use per metre of shelf) and found the evidence of increasing density of use with increase of age [154]. There was no aging found but the low citation density was attributed to the inaccessibility of the old volumes which were kept in the basement of the library.

In a study Christavo came to the conclusion that articles from developed countries aged the literature faster than articles from developing countries [155]. This indicates that the difference in aging is related to the international or local relevance of research topic. Aversa in a diachronous study using Journal Citation Reports data from 1972 to 1980, concluded that for one group of citations showed peak in the third year and declined thereafter while that for the highly cited group showed peak in the sixth year and then dropped off slowly [156]. Two types of aging pattern is related to the role of papers in subsequent research. Technical and experimental papers peaked later and aged less rapidly than papers with
specific research findings. Obsolescence studies enable
collection management in libraries, help in information
generation, study of growth of literature etc.

3.4.4 Bibliographic coupling and clustering

In 1962 Kessler reported on bibliographic coupling
between scientific papers. According to him a number of
papers have a meaningful relation to each other when they
have one or more references in common. When the unit of
coupling is a single item of references in common then it
is said to have similarity in content between the two
papers. This study helps to identify related papers in a
specific subject.

Clustering occurs when one item of paper is referenced
by a number of journals. All these journals form a cluster.
Carpenter and Narin studied clustering of journals in the
disciplines of Physics, Chemistry and Molecular Biology
[157]. This aids in classifying related journals more
precisely based on their relationship. This is based on the
assumption that journals which deal with the same subject
area may have similar referencing pattern and the journals
which deal with the same subject may refer to each other.
Cluster studies are indicators of birth, growth and death
of science and their social structure. Cluster studies were
done by using bibliographic coupling but now this is
replaced by co-citation, a measure developed by Small. Co-
citation changes with time but bibliographic coupling is static.

3.4.5 Co-citation

Co-citation studies help in mapping of literatures. When one paper cited two other papers together it is implied that the two papers are related. If the papers are cited together by more authors, then their relation is clearly indicated. Earlier studies by Small, shows links between documents which are obtained by Co-citation counts [32]. Such documents are arranged in a cluster with the highly co-cited document in the centre of cluster. As new papers are published, the co-citation links also change. Co-citation analysis can be done by using data collected from databases in computer. It helps to form clusters of documents, authors etc. Another type of study co-citation context analysis enables to produce research reviews and Swanson gives the importance of such studies in information Science [158].

Clusters of cited documents are groups made evident by co-citation strengths. The strength of relationship is proportional to the number of times the papers are cited together. This technique is used in citation indexing in ISI databases.

Citation analysis have been applied in various disciplines successfully mainly for journal evaluation.
Though there are some limitations such as self-citation, multiple authorship, synonyms, merging or splitting of journal titles etc to such studies, the advantages are more. It helps to classify journals according to scientific importance based on their impact on research, measure scientific influence and productivity, enables proper management of collection in libraries, information retrieval in computerised services etc. Citation studies are becoming more easier and relevant by using online databases.

3.5 Current Trends

Informetric techniques are used in the identification of trends in a subject and also in the study of scientific communication. Informetrics is accepted as a research area that gives additional understanding of the form and structure of scientific communication. Some of the uses are for studying:

1) growth of a subject and its literature
2) evaluate quality of research of an individual, an organisation or a country
3) productivity of an individual scientist
4) study history of science and science policy
5) obsolescence or aging of scientific literature
6) evaluating individual journals or a group of journals especially for acquisition decisions.
7) identify users of different subjects  
8) authorship trend of scientific literature  
9) measure usefulness of SDI services  
10) develop experimental models correlating or bypassing existing ones.

Of the informetric distributions, the most used is Bradford's law and its various refinements. It is used to assist in designing information systems, rationalizing library services and in making more economic and fruitful use of periodicals. Brookes gave the use of Bradford's law in -

1) computerised bibliographic search systems (Medlars)  
2) management of special libraries  
3) discarding of 'aged' periodicals  
4) planning special library systems  
5) subject bibliography compilation without difficulty.

The two characteristics of Bradford's law are its universality and stability. The universality states that the law holds for all subjects at all times. The stability means violation of conditions for the validity of the law such as narrow time span of bibliography or narrow subject definition is not affecting the law significantly.

Research on informetric techniques applied to various disciplines have been done which has led to an increase in number of papers on the topic. Most of the studies were conducted to evaluate the scientific publications.
scientists, research organizations etc. Many reports on informetric laws and its applications are also found. Citations are observed to be valid measures of quality in most of the studies though some show citations are not true measure of quality. In such cases combination of other measures such as expert opinion, can also be taken into account for forming conclusions.

Recently informetric measures of research productivity and quality are applied by decision makers to enable proper utilization of available resources. Quantitative methods in science and technology assist in determining funding priorities for research in the present context of economic recessions. Quantitative studies using informetric methods are also taken as science policy indicators in many countries of Europe. Such studies are published in journals like 'Research policy' 'Scientometrics' and other publications [159]. The use of informetric methods in science policy decision-making has generated the same range and level of criticism as in the use of citation analysis. But these studies can be considered as one of the many sources of information for science policy indicators.

Applications of informetric methods has been necessitated by the information explosion. By the development of computer databases most of the studies are now done by gathering data online. Stefaniak gives review
on works done in U.S. and Europe [82]. A variety of measures for downloading data are available on "The Bibliometrics Toolbox" created by Brooks [160].

As applied to library and information science, informetric analyses have also been used for book and periodical acquisitions, library use studies, weeding of obsolete materials etc. Now these methods are applied to evaluate the structure of literature in various disciplines. Thus the quantitative methods which were termed 'Bibliometrics' to denote 'written communication' have progressed to information science which makes the term 'informetrics' the most appropriate one in the present context. Informetrics has thus become very significant and effective tool in research for quantitative and qualitative measurement of human knowledge.

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