XVI, 67% of all respondents (about half of those who read JACS and over three-fourths of those who do not) state that the subscription price is not the reason. Thus, other reasons are involved; for example, the subject matter may not be of interest, the format or amount of material in the journal may be a deterrent, etc.

A range of potential subscription prices was offered for their consideration to provide an estimate of the potential market for a JACS summary journal and to gauge the price sensitivity. The results of the inquiry (Table XVI) indicate that about 30% of the respondents would subscribe to a JACS summary journal if the subscription price were \$15–20. Of course, the proportion of those expressing an intent to subscribe who would actually carry out that intent is subject to a number of factors (e.g., the intensity of a promotional campaign). However, even a drastic reduction in the percentages indicated would translate into thousands of subscriptions if the survey results can be projected to the total ACS membership not subscribing to JACS (approximately 100 000).

Production Economics. It was stated in the Purpose and Objectives section of this report that adoption of a dual journal system for the publication of JACS would be expected to result in savings of 25–30% of the production costs. This expectation was verified during the publication of the three sample issues of JACS by a comparison of the costs for the dual journal samples and the regular journal issues published concurrently.

FUTURE PLANS

Although no "mandate" is apparent for conversion of JACS to a dual journal, as exemplified by the sample issues, strong evidence has been obtained of an interest in, and need for, a summary journal. There are no plans at present to publish JACS by the methods used to produce the sample archival journals. However, it is planned to investigate the potential of a summary journal that would be a companion to the current, conventionally published JACS (or to other ACS journals), as well as other alternatives to the present journal system. Potential variations might be (a) a summary journal plus a microfiche version of the regular journal, (b) a summary journal plus requested articles, (c) a summary journal that would contain summaries of articles from more than one journal. It is possible that favorable reaction to one or more of the schemes might permit an experimental journal system to be tried for a year or two.

ACKNOWLEDGMENT

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Influence and Interrelationship of Chemical Journals†

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The structure and interrelations of the chemical journal literature are investigated as a preparatory step for studies of chemical research activity. Newly developed techniques of bibliographic citation analysis are used to construct influence measures for individual journals and for the subfields of chemistry into which the journals have been classified. Hierarchical influence diagrams are presented to display the influence and interrelations of the chemical subfields, and of the individual journals themselves.

The structure of the scientific literature has been of continuing interest to chemists. The scientific literature can help to define the interrelationships of the different subfields of chemistry by revealing patterns of influence and information flow. Within the scientific literature, the journal literature is the accepted formal communication network of science and reflects the mechanisms by which knowledge is transmitted and evaluated. The use of quantitative measures to evaluate the influence of scientific research in a given subfield of science or within a given institution can serve as a management aid in assessing the effectiveness of the scientific enterprise as well as providing data for science policy studies.

The appeal of citation analysis is attested to by its recurrence in the scientific literature during the last 50 years. In 1927, a modest paper published by Gross and Gross was the first to use citations to evaluate the importance of scientific journals; its concern was the adequacy of the chemical library collection at Pomona College.[1] Gross and Gross tabulated the references from the *Journal of the American Chemical Society* in 1926 and used these to rank the importance of the cited journals to American chemistry students. There followed at least 20 papers which used the same technique, the direct counting of citations from one or a small group of journals, as a measure

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of the importance of the cited journals to an area of science.

In order to perform a comprehensive analysis of the scientific literature and the disciplines contributing to it, new bibliometric techniques have been developed. In recent papers, application has been made to biomedicine[2] (Narin, Pinski, and Gee, 1976) and to physics[3] (Pinski and Narin, 1976). In chemistry, these techniques enable one to describe the flow of influence among the subfields of chemistry and among the chemical journals themselves.

The analysis described in this paper was carried out in preparation for further studies of chemical research activity, in particular the publishing patterns of individual research organizations. With a knowledge of these patterns, administrators will have a potential tool for evaluating programs and ascertaining growth or change over time, and funding agencies will have objective criteria for analyzing the effect of policy decisions.

The influence weight methodology, described below, has been applied to the chemical journal literature. These applications will be presented following the description of the influence weight methodology.

THE INFLUENCE WEIGHT METHODOLOGY

The three journal influence measures to be constructed are called the influence weight, influence per publication, and total influence. The information describing the flow of influence among journals is contained in a square array, c_{ij}, called the citation matrix. A term c_{ij} in the citation matrix indicates both the number of references journal i gives to journal j and the number of citations journal j receives from journal i. Thus the term reference is used when designating the issuing journal, while the term citation designates the receiving journal.

The time frame of a citation matrix must also be clearly understood in order that a measure derived from it may be properly interpreted. If the citation data are based on references issued in 1973, they may refer to papers published in any year up to and including 1973. In general, the papers issuing the references will not be the same as those receiving the citations. Any conclusions drawn from such a matrix assume an ongoing, relatively constant nature for each of the journals. It is assumed that journals have not changed in size relative to each other, and that they represent a constant subject area. Journals in rapidly changing fields and new journals must therefore be treated with caution.

The citation matrix for the set of journals discussed in this paper was developed from the citation tapes of the *Science Citation Index* (SCI).[4] These citation counts were originally assembled for a National Science Foundation (NSF) study investigating the relationship between the amount of support and publication output for all fields of science. The data tapes contain five million references, from the 2300 journals covered by the SCI, to a wide variety of publications including journal articles, books, meetings, private communications, and so forth. Of the 2300 journals, 200 were classified as chemical journals and included in this study. After unifying all variants of the abbreviation for each journal, a journal by journal tabulation was obtained, covering the citations to and from each of the journals. These raw citation counts were then organized into a citation matrix.

Starting with the citation matrix, an algorithm was developed for the calculation of the size independent influence weight for each journal. The citation matrix may be thought of as an "input-output" matrix, with the medium of exchange being the citation. Each journal gives out references and receives citations; it is above average if it has a "positive citation balance", i.e., receives more than it gives out. The starting point for the calculation is the formation of the citation ratio for each journal. This is given by

$$\text{citation ratio} = \frac{\text{total no. of citations } \textit{to} \text{ the journal}}{\text{total no. of references } \textit{from} \text{ the journal}} = \frac{i\text{th column sum of citation matrix}}{i\text{th row sum of citation matrix}}$$

If a journal's citation ratio is greater than one, then the journal is a cited journal more than a referencing journal. This citation ratio is actually the first-order approximation (an approximation in which all citations to a journal are weighted equally) in an iterative process of finding influence weights.

In the next order of approximation, a reference from any journal is weighted with the weight it received in the first approximation, yielding a set of second-order weights. This process is continued and rapidly converges to a stable, self-consistent set of influence weights. The rigorous mathematical formulation of this procedure as an eigenvalue problem has been published elsewhere.[3]

The set of influence weights thus generated provides a size-independent measure for each journal. There is no tendency for a journal to have a higher or a lower weight due to its size, whether measured by the number of publications or by the average length of its publications. For some purposes it is useful to have an influence measure calculated on a per publication basis. From the mathematical formulation of the problem it turns out that the influence per publication is given by

$$\text{influence per publication} = \text{influence weight} \times \text{references per publication}$$

A journal which contains longer papers, such as a review journal, will generally have larger influence on a per publication basis than will a journal which publishes original research.

The third measure of influence is the total influence of a journal defined by

$$\text{total influence} = \text{influence per publication} \times \text{no. of publications}$$

Two journals could have the same influence weight and the same influence per publication and yet have widely different total influence, due solely to the difference in the number of publications.

Table I lists the three influence measures together with the average number of references per publication and average number of yearly publications for the 107 chemical journals for which there were adequate citation data. The different roles of the three influence measures are apparent from an examination of the listings. *Chemical Reviews*, although having an influence weight which is not high, has by far the highest influence per publication. This is due to the large "target size" of its publications as measured by the large number of references from the average publication: 209. While, in general, publications in review journals tend to be long, the number of publications per year is small, usually fewer than 50. As a result, the total influence of a review journal is usually lower than that of comparably prestigious research journals. Letter journals, which publish shorter communications, have a smaller target size. Thus, although *Tetrahedron Letters* has a higher influence weight than *Tetrahedron*, it has a lower influence per publication because of the shorter length of its publications. *Tetrahedron Letters* has a larger total influence by virtue of its larger number of publications.

The *Journal of the American Chemical Society* has a high influence weight, the highest influence per publication of any nonreview chemistry journal and the highest total influence.

It should be emphasized that our influence measures could properly be called "citation influence measures". There are numerous factors which are relevant to a journal that con-

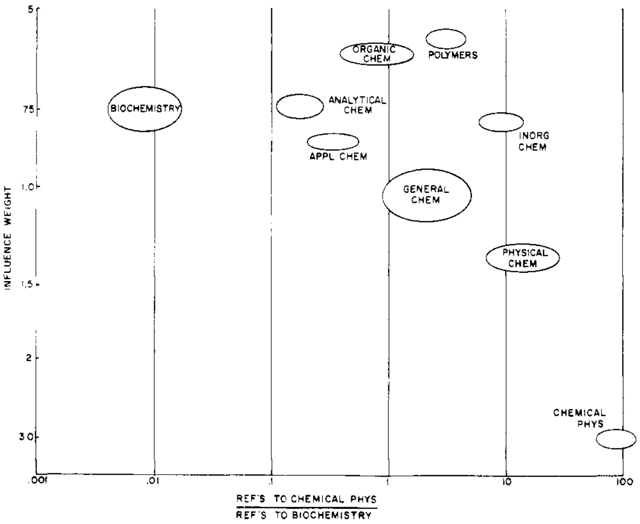

Figure 1. Influence structure for the chemical literature.

tribute to these de facto measures: true merit, journal circulation, availability, degree of specialization, country of origin, language. One may wish to investigate the extent to which these factors individually correlate with our measure; their collective effects are implicitly accounted for in the citation influence calculation.

In order to analyze the influence flow and the interrelations among the subfields of chemistry, the chemical journals were classified into their appropriate subfields. In any such classification one must deal with a set of general journals. These journals cannot be classified as belonging to a single subfield, but may contain articles in all or several of the subfields. The prototype journal in this category is the *Journal of the American Chemical Society*. Also in this category is the *Journal of the Chemical Society* (*London*) which now appears in six sections. The sectional devisions have been formed and changed over the years. In a large automated citation study, because many citations appear as citations to the nonspecific form "*J. Chem. Soc.*", one is forced to combine the sections and deal with one undifferentiated general journal. There are also journals, such as *Science*, which are general not just at the subfield level, but at the major field level as well. Journals in this category are referred to as multidisciplinary journals.

Table I lists the chemical journals covered in the SCI as assigned to seven subfields. The largest of these groups is that of general chemistry journals. There is no unique way to choose a set of subfields. By introducing finer and finer distinctions, the number of subfields can be indefinitely increased.

There are certain natural journal groupings corresponding to the main subfields of chemistry: organic chemistry, inorganic and nuclear chemistry, physical chemistry, and analytical chemistry. Electrochemistry and crystallography have been included in physical chemistry. Polymer and macromolecular science journals were grouped together into the subfield called polymers. The applied subfield consists of applied and industrial chemistry but not chemical engineering journals; admittedly, the dividing line between industrial chemistry and chemical engineering is not sharp, but we have included the journal *Industrial and Engineering Chemistry*

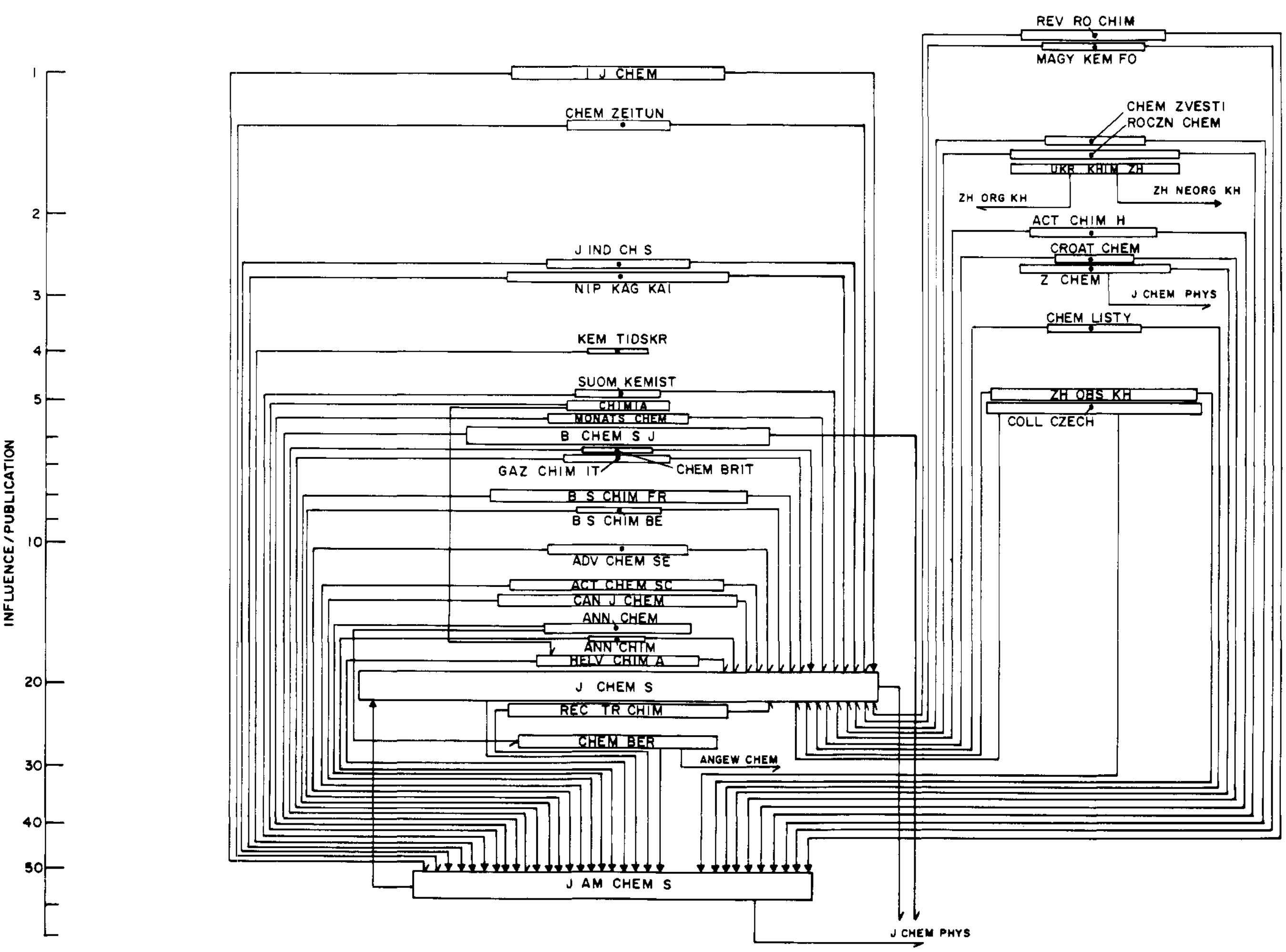

Figure 2. Influence map for general chemistry journals.

Table I. Journal Assignments and Influence Measures (1973 Data)

	Infl wt	Refs/pub	Infl/pub	Pubs	Tot infl
General Chemistry					
ACC CHEM RE	1.18	44.5	52.5	63	3306
ACT CHEM SO	0.99	12.6	12.5	492	6160
ACT CHIM H	0.20	11.1	2.2	182	409
ADV CHEM SE	0.45	22.8	10.3	205	2103
AN AS QUIM	0.04	11.3	0.5	34	17
AN REAL SOC	0.07	12.0	0.8	147	118
ANN CHEM	0.97	16.2	15.7	239	3748
ANN CHIM	1.58	9.9	15.6	37	578
ANN CHIM PH	0.51	26.8	13.7	61	835
ARM KHIM ZH	0.09	5.0	0.4	191	86
B CHEM S J	0.48	12.6	6.1	1013	6189
B S CHIM BE	0.57	15.0	8.5	73	623
B S CHIM FR	0.40	19.5	7.9	708	5572
CAN J CHEM	0.76	17.8	13.6	615	8339
CHEM BER	1.53	17.2	26.4	436	11489
CHEM BRIT	0.44	14.2	6.3	54	342
CHEM LETT	0.08	6.8	0.6	393	216
CHEM LISTY	0.12	29.7	3.5	98	339
CHEM REV	0.71	209.0	148.6	27	4011
CHEM SOC RE	1.05	79.5	83.2	22	1831
CHEM ZEITUN	0.05	24.3	1.3	114	145
CHEM ZVESTI	0.14	10.3	1.4	110	155
CHIMIA	0.45	11.5	5.2	111	575
COLL CZECH	0.43	11.8	5.1	499	2535
CROAT CHEM	0.17	15.0	2.5	67	170
GAZ CHIM IT	0.48	13.8	6.6	122	808
HELV CHIM A	1.10	16.8	18.4	273	5015
I J CHEM	0.11	9.4	1.0	501	526
J AM CHEM S	2.20	24.5	53.8	1813	97612
J CHEM EDUC	0.61	5.5	3.3	427	1426
J CHEM S	1.41	14.4	20.4	2962	60277
J CHIN CHEM	0.06	8.7	0.5	27	14
J IND CH S	0.34	7.7	2.6	219	574
J LABEL COM	0.07	7.1	0.5	101	50
KEM KOZLEM	0.01	48.7	0.3	43	13
KEM TIDSKR	1.38	2.9	3.9	41	161
KHIM PRIR S	0.08	5.5	0.5	319	147
MAGY KEM FO	0.09	9.3	0.9	117	102
MAGY KEM LA	0.02	8.3	0.2	65	10
MONATS CHEM	0.46	11.5	5.3	216	1136
NIP KAG KAI	0.44	6.2	2.7	548	1496
REC TR CHIM	1.66	13.2	21.9	136	2973
REV RO CHIM	0.08	11.4	0.9	229	206
ROCZN CHEM	0.14	10.5	1.5	308	450
SUOM KEMIST	0.39	12.6	4.9	76	372
UKR KHIM ZH	0.29	5.4	1.6	320	499
USP KH	0.05	122.9	6.2	80	498
Z CHEM	0.33	7.7	2.6	249	640
ZH OBS KH	0.44	11.2	4.9	478	2366
Physical Chemistry					
ACT CRYST	2.58	11.1	28.6	796	22805
APPL SPECTR	0.97	8.5	8.2	96	786
BER BUN GES	1.24	16.7	20.6	168	3462
CATAL REV	0.19	85.4	15.9	8	127
ELECTR ACT	0.45	12.6	5.7	143	818
FARADAY DIS	3.17	19.6	62.1	41	2545
INT J QUANT	1.07	16.0	17.1	119	2033
INT J RAD P	0.25	16.4	4.1	50	206
J APPL CRYS	0.52	6.8	3.6	103	368
J CATALYSIS	0.65	13.3	8.7	221	1918
J CHEM THER	0.26	11.7	3.1	106	324
J CHIM PHYS	0.69	15.1	10.4	223	2330
J COLL I SC	0.36	14.6	5.3	279	1470
J CRYST GR	0.55	12.4	6.8	151	1027
J ELCHEM SO	0.69	11.3	7.8	395	3069
J ELEC CHEM	0.24	13.9	3.4	391	1318
J MOL SPECT	2.38	13.7	32.6	200	6520
J MOL STRUC	0.35	14.5	5.2	183	944
J PHYS CHEM	1.52	18.9	28.7	639	18358
J QUAN SPEC	1.87	13.2	24.7	131	3233
J SOL ST CH	0.20	14.6	2.9	176	503
KOLL ZH	0.17	6.9	1.2	289	341
KOLLOID-Z	0.48	13.8	6.6	134	883
MATER RES B	0.41	8.2	3.4	188	632
Physical Chemistry (continued)					
MOLEC CRYST	1.22	15.2	18.5	95	1760
RADIOCH ACT	0.59	11.8	6.9	60	415
RUSS J PH R	0.54	6.1	3.3	789	2604
SOV PH CR R	0.68	7.8	5.3	307	1630
SPECT ACT	1.55	15.3	23.7	245	5809
SPECT LETT	0.17	8.1	1.4	95	133
THEOR CHIM	1.32	19.5	25.7	126	3241
Z KRISTALL	2.28	10.5	23.9	85	2030
Z PHYS CHEM[a]	1.21	11.6	14.0	274	3847
ZH STRUK KH	0.31	10.6	3.3	221	729
Analytical Chemistry					
ANAL LETTER	0.40	7.2	2.9	123	353
ANALUSIS	0.12	8.5	1.1	85	90
ANALYST	0.82	9.7	7.9	131	1039
ANALYT CHEM	0.75	20.9	15.6	603	9401
ANALYT CHIM	0.51	8.9	4.5	344	1555
J AOAC	1.04	5.1	5.3	321	1692
J CHROM SCI	0.94	11.9	11.2	118	1317
J CHROMAT	0.53	10.7	5.6	631	3553
J RAD CHEM	0.20	6.4	1.3	143	186
J THERM ANA	0.34	9.7	3.3	45	147
JAP ANALYST	0.02	25.9	0.5	231	119
MICROCHEM J	0.31	7.5	2.3	86	201
MIKROCH ACT	0.43	9.9	4.2	124	525
TALANTA	0.49	10.1	4.9	155	763
Z ANAL CHEM	0.76	6.4	4.9	249	1210
ZH ANAL KH	0.15	8.4	1.3	463	602
Organic Chemistry					
CARBOHY RES	0.22	14.7	3.3	361	1195
J HETERO CH	0.29	11.0	3.2	229	733
J ORG CHEM	0.78	17.0	13.3	1266	16812
J ORGMET CH	0.24	21.6	5.2	798	4126
KHIM GETERO	0.06	7.9	0.5	370	189
OMR-ORG MAG	0.11	16.9	1.9	142	268
ORG MASS SP	0.46	12.9	5.9	158	931
SYNTHESIS	0.14	18.5	2.6	197	512
TETRAHEDR L	1.20	8.5	10.1	1406	14229
TETRAHEDRON	0.67	18.6	12.5	552	6894
ZH ORG KH	0.18	10.8	2.0	489	973
Inorganic and Nuclear Chemistry					
COORD CH RE	0.16	176.8	27.6	26	719
INORG CHEM	0.87	19.9	17.2	677	11651
INORG NUCL	0.48	7.3	3.5	263	923
J INORG NUC	0.47	12.1	5.6	632	3546
REV CHIM MI	0.19	16.3	3.2	48	153
Z ANORG A C	0.86	12.6	10.8	280	3027
ZH NEORG KH	0.33	7.6	2.5	589	1467
Applied Chemistry					
ANGEW CHEM	1.64	25.1	41.1	295	12122
ANGEW MAKRO	0.10	12.1	1.2	98	117
CHEM IND L	1.36	6.2	8.4	282	2377
CHEM TECH	0.19	5.9	1.1	156	175
CHEMTECH US	0.10	8.2	0.8	85	71
CHIM IND M	0.26	15.0	3.9	101	395
FLUORIDE	0.08	12.1	1.0	28	27
IND CHIM BE	0.06	37.1	2.4	48	115
IND ENG CH	1.53	10.4	16.0	236	3774
J AM LEATH	3.82	4.5	17.1	30	512
J AM OIL CH	0.61	11.7	7.2	151	1084
J APPL CH B	0.66	8.7	5.7	94	536
J OIL COL C	0.53	5.3	2.8	54	150
J PAINT TEC	1.14	5.4	6.2	65	400
J PRAK CHEM	0.51	12.0	6.1	155	949
J S COSM CH	0.18	15.5	2.8	61	170
J SCI IND R	0.14	60.2	8.3	47	388
MANUF CH AE	0.01	55.4	0.8	7	5
PRZEMY CHEM	0.12	2.5	0.3	194	58
RES DEVELOP	0.33	4.5	1.5	51	76
SEPARAT SCI	0.38	11.8	4.5	57	256
SILIKATY	0.09	5.5	0.5	32	15
STARKE	0.14	12.0	1.6	66	108
ZH PRIK KH	0.24	7.8	1.9	363	682

Table I *(Continued)*

	Infl wt	Refs/pub	Infl/pub	Pubs	Tot infl		Infl wt	Refs/pub	Infl/pub	Pubs	Tot infl
		Polymers						Polymers (continued)			
EUR POLYM J	0.19	12.7	2.5	134	331	MACROMOLEC	0.39	16.9	6.6	152	1003
J ADHESION	0.62	7.5	4.7	17	79	MAKROM CHEM	0.38	12.2	4.7	294	1367
J APPL POLY	0.29	10.3	3.0	318	944	POLYM ENG S	0.18	11.7	2.2	64	138
J MACRO SCI	0.14	20.5	2.9	151	436	POLYM J	0.15	14.6	2.2	114	255
J POL SC	0.54	12.0	6.4	897	5741	POLYMER	0.37	12.4	4.6	127	589
KOBUNSH KAG	0.09	6.6	0.6	291	172	VYSO SOED	0.20	8.5	1.7	665	1137

[a] Z PHYS CH F and Z PHYS CH L were unified into the undifferentiated form Z PHYS CHEM because most of the cites to them could not be uniquely identified.

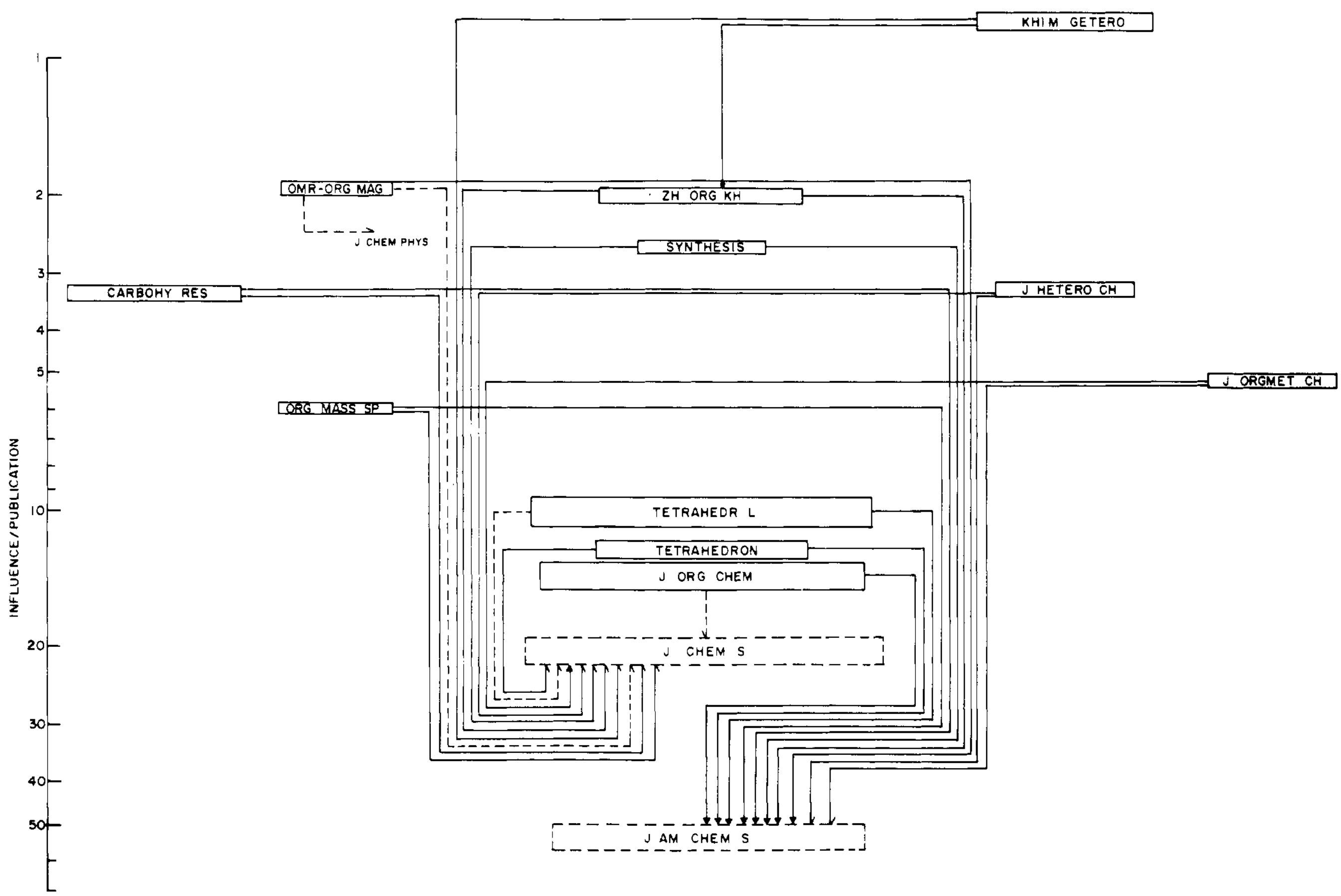

Figure 3. Influence map for organic chemistry journals.

(with the sections combined) in applied chemistry.

Pharmaceutical chemistry journals have not been included in this study although pharmaceutical chemistry could have been included in applied chemistry or regarded as a separate subfield.

Classification of the chemistry journals into subfields makes it possible to analyze the flow of influence among subfields by considering the subfields themselves as units of study. In the overall flow of influence through the fields of science, there is a hierarchy which can be represented by the scheme

biology → chemistry → physics → mathematics

The subfields of chemistry may be thought of as spread out in a spectrum from biology to physics. The interface between chemistry and biology has itself developed into a major field, namely biochemistry. Although the journal *Biochemistry* is published by the American Chemical Society, it is one of the central journals to the literature of biochemistry, and only a small proportion of its references are directed at chemistry journals.

The interface at the other end of the spectrum presents a different situation. Physical chemistry has remained within

Table II. Cross Citing between Three Key Journals[a]

References from	Citations to JACS	JCP	PR
JACS	15941	3085	123
JCP	899	10866	2397
PR	66	1888	25380

[a] JACS is *Journal of the American Chemical Society*, JCP is *Journal of Chemical Physics*, and PR is the *Physical Review*.

chemistry, and as a subfield is not a borderline area between chemistry and physics. Chemical physics does provide an interface linking chemistry and physics. The linking role of the *Journal of Chemical Physics* (JCP) is clearly stated on the inside cover of the journal: "...to bridge a gap between journals of physics and journals of chemistry.... The artificial boundary between physics and chemistry has now been in actual fact completely eliminated and...research which is as much the one as the other". That this journal is a true borderline journal linking the chemistry and physics literatures may be seen by examining the 3 × 3 matrix of citations between the *Journal of the American Chemical Society*

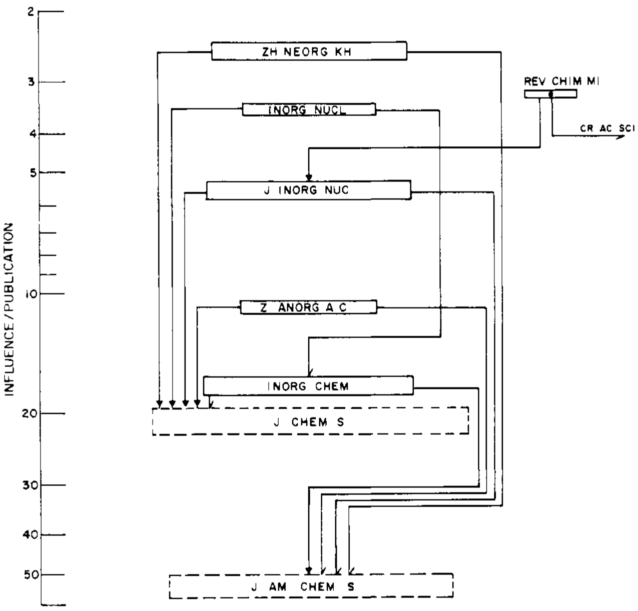

Figure 4. Influence map for inorganic and nuclear chemistry journals.

(JACS), JCP, and *Physical Review* (PR) shown in Table II. Although the direct physics chemistry linking is too weak to establish a strong hierarchical relationship, the inclusion of chemical physics provides a strong connection with both chemistry and physics, establishing the strong hierarchical relationship

chemistry → chemical physics → physics

This means that chemistry refers to chemical physics more often than it is cited by chemical physics, and chemical physics refers to physics more often than it is cited by physics.

Although influence measures for individual biochemistry and chemical physics journals are not presented here, the journals in each of these areas have been aggregated, and both of these aggregates are included as subfields along with the seven journal subfields discussed above. The 9 × 9 citation matrix was then constructed and the subfield influence measures were derived. These are given in Table III. The different subfields of chemistry interact to a very different degree with the two "endpoints" of the chemistry spectrum: biochemistry and chemical physics. The ratio

Table III. Influence Measures and Publication Data for the Subfields of Chemistry

Subfield	Infl wt	Refs/pub	Infl/pub	Pubs	Tot infl
GEN CHEM	1.043	15.72	16.40	16 089	263 809
BIOCHEM	0.747	20.65	15.42	12 049	185 749
ANAL CHEM	0.737	11.78	8.69	4 243	36 860
ORGAN CHEM	0.598	14.24	8.52	5 968	50 855
INORG CHEM	0.776	14.47	11.23	2 515	28 244
APPL CHEM	0.846	12.22	10.34	2 762	28 571
POLYMERS	0.562	11.37	6.39	3 224	20 614
PHYS CHEM	1.340	12.37	16.58	7 188	119 206
CHEM PHYS	3.218	15.71	50.54	3 220	162 732

$$\frac{\text{references to chemical physics}}{\text{references to biochemistry}}$$

calculated for each subfield, is a measure of the physical to biochemical orientation of each subfield.

This suggests a diagrammatic representation of the chemical literature as a generalized hierarchy shown in Figure 1. The vertical coordinate is the influence weight, with values increasing in the downward direction, while the horizontal coordinate is the above ratio. A logarithmic scale is used for both coordinates. Physical orientation of subfields increases toward the right. The chemical physics grouping, at the lower right corner of the map, is seen to have by far the highest influence weight due to the exceptional role of the *Journal of Chemical Physics*. The grouping has a strongly positive citation balance with a wide range of chemistry journals across the whole subfield spectrum. Among the chemistry subfields, physical chemistry has the highest influence weight, with general chemistry next, although from Table III we can see that their influence per publication measures are almost equal. In total influence the general grouping has by far the highest value owing to its size.

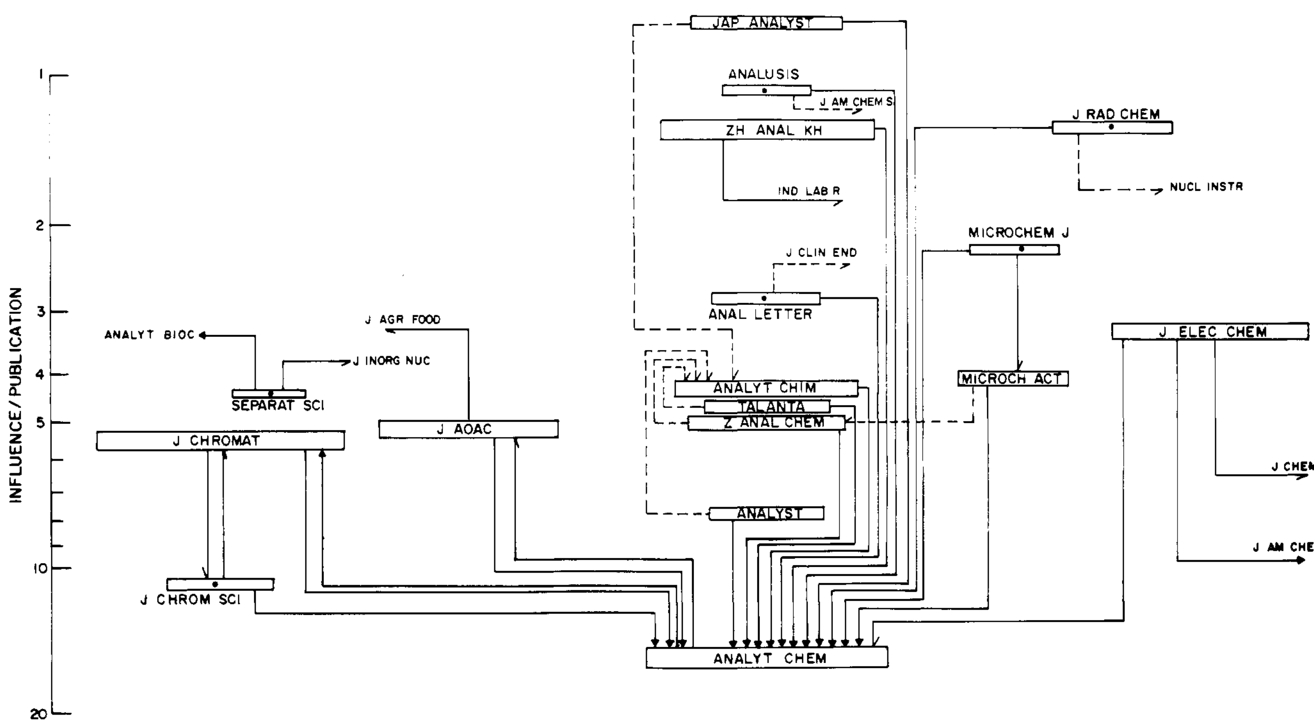

Figure 5. Influence map for analytical chemistry journals.

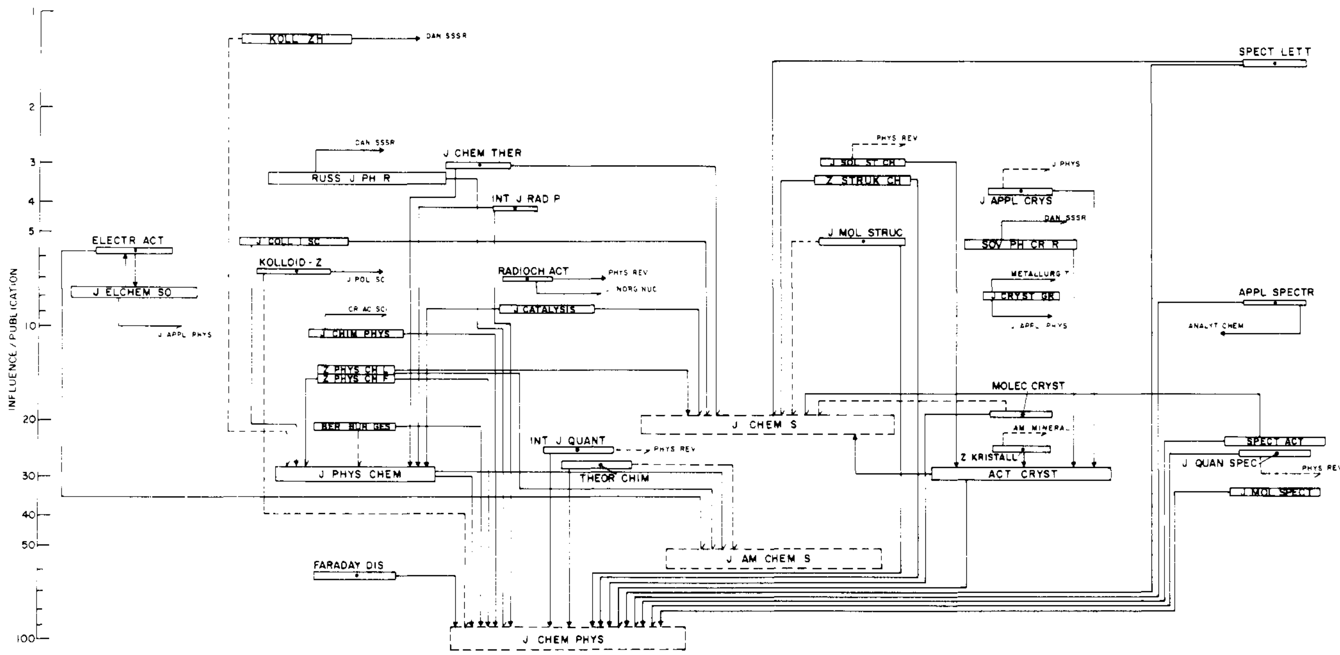

Figure 6. Influence map for physical chemistry journals.

INFLUENCE MAPS FOR INDIVIDUAL JOURNALS

At the next level of detail, the individual journals are considered as the basic units of analysis. The influence maps for chemistry journals, Figures 2–7, were constructed using the influence measures given in Table I. The following conventions apply to these maps:

(1) A solid rectangle is used to represent journals within the subfield or subfields being presented on a given map. SCI journal abbreviations are used for all journals. The area of a rectangle is proportional to the size of a journal, as measured by the number of articles, notes, and reviews in the Corporate Index of the SCI in 1973.

(2) The vertical scale shows influence per publication for each journal on a log scale. Weights for a set of units tend to be distributed in a log uniform rather than in a uniform manner, and so use of a log scale results in less crowding for the lower weight units. Only journals reporting original research appear on the maps. Review journals, because of the large size of their individual publications, tend to have exceptionally high influence per publication. Their role in the literature is different from that of journals that report primarily original research; it is not, therefore, appropriate to compare the influence per publication of review and research journals.

(3) The horizontal direction is used to separate either different subfields appearing on the same map, or journals with different specific foci. Journals in the same column tend to be more similar to each other than to journals in neighboring columns.

(4) Arrows are directed from a journal to the other journals, exclusive of itself, to which it refers most frequently. Usually, two arrows are drawn from each journal showing the two other journals that are most frequently referenced; occasionally three are given if the number of references to the second and third are close, or there may be only one if a single arrow best characterizes the referencing priority of the journal. An arrow with a full head is used for a first arrow (largest number of references) while a half head is used for a second or third arrow. A dotted arrow is used for a secondary arrow which is considerably weaker than the primary arrow. If an arrow is directed to a journal which is not classified as being in the subfield under study, the "target" journal may be treated in one of several ways:

(a) If the journal is of exceptional importance to the journals within the subfield of interest it will appear in a dashed rectangle located on the vertical scale by its influence per publication. An example of this is the appearance of the two large general journals on each of the subfield maps except for the analytical chemistry map.

(b) Arrows directed out of the subfield to journals which are not of central importance to the field are generally short arrows leading to the unenclosed journal name. For this case there is no significance to the vertical placement of the cited journal.

Figure 2 is the map for general chemistry journals. All sections of the *Journal of the Chemical Society* have been combined into a single unit which must then be considered a general journal. The standard pattern for general chemistry journals is to refer most frequently to the *Journal of the American Chemical Society* and second to the *Journal of the Chemical Society*. The journals have been placed into two columns, with the journals from the Eastern European countries appearing at the right.

The organic chemistry journals, shown in Figure 3, and the inorganic and nuclear chemistry journals, shown in Figure 4, also refer most frequently to the two large general journals. This referencing pattern may be contrasted with the referencing pattern shown in the map for analytical chemistry journals, Figure 5, where it is apparent that a higher percentage of the references remain within the subfield, with *Analytical Chemistry* being the central journal.

Physical chemistry journals including crystallography, spectroscopy and electrochemistry journals are mapped in Figure 6. The most striking feature of this map is the importance of the *Journal of Chemical Physics*, which is itself a borderline journal between chemistry and physics.

In Figure 7, applied and polymer physics journals are shown. The *Journal of Polymer Science* (a combination of the individual sections) is the central polymer journal. The applied chemistry grouping does not form a cohesive citation unit, but refers to a variety of basic chemistry and chemical engineering journals.

From these figures, it is evident that journals are fairly uniformly distributed on the vertical logarithmic influence per publication scale. There are large differences in influence

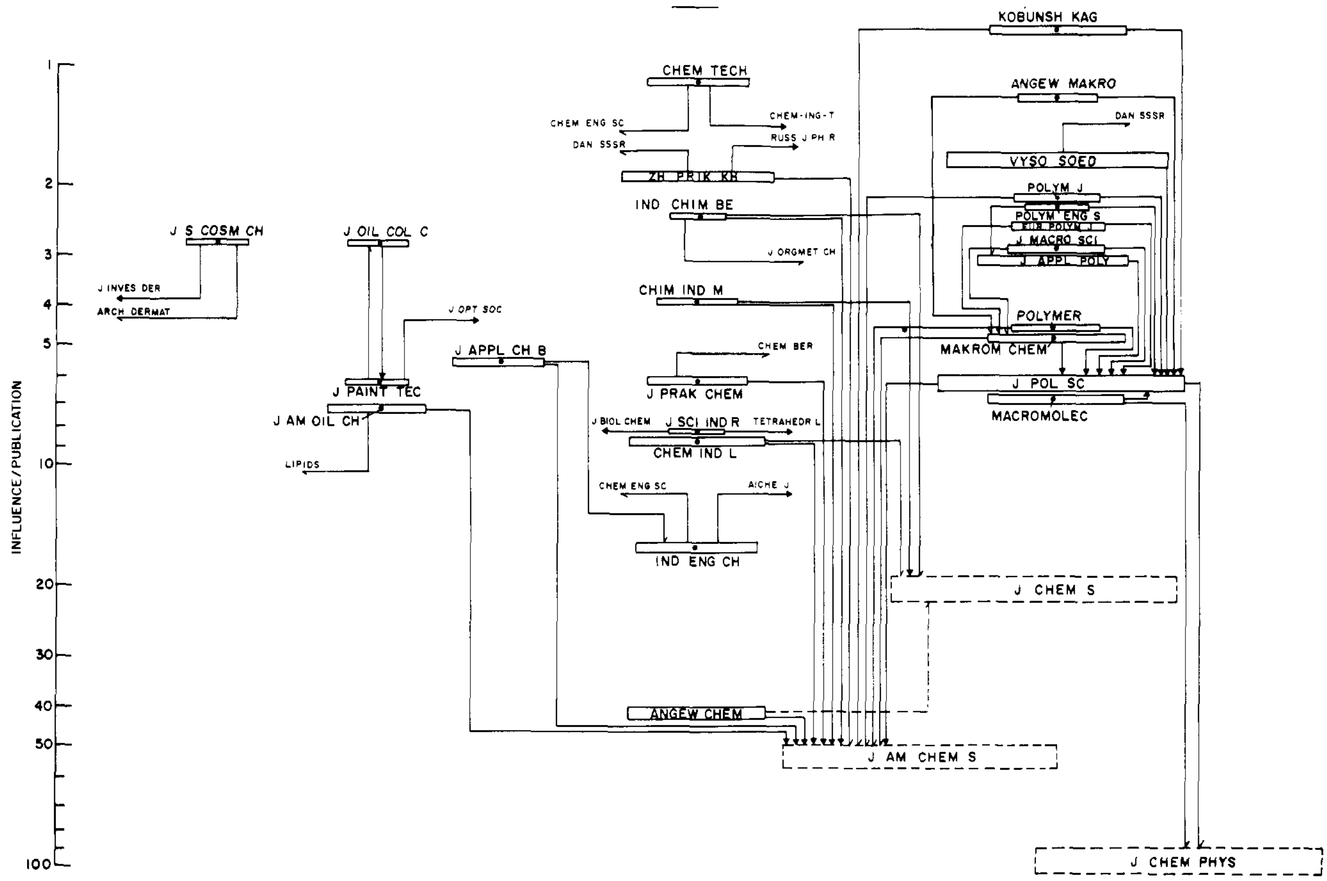

Figure 7. Influence map for applied and polymer chemistry journals.

between journals at the top and those at the bottom of the map.

FURTHER APPLICATIONS

As mentioned in the Introduction, the methodology established in this paper may be used to evaluate the research activities of large organizations. Particularly important and interesting research organizations can be found within the graduate departments of American universities. The most challenging aspect of university analysis has been to find methods for ranking graduate departments. The only widely accepted rankings are those given by two surveyed opinion reports done for the American Council on Education in 1966 and 1969. Because of the subjective nature of opinion polls, many workers have attempted to find objective indices of quality.

Application of the techniques derived in this paper to the analysis of university publishing patterns yields objective rankings of the research influence of chemistry graduate departments. These literature-based ratings correlate highly with subjective results of surveyed opinions. Furthermore, publication analysis allows the separation of a university's rating into one factor related to quality of published research and into another factor related to quantity of publications. We plan to discuss this in a future paper.

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(4) SCI is a registered trademark of the Institute for Scientific Information, Philadelphia, Pa.