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STUDYING LEADERSHIP AND SUBDISCIPLINARY STRUCTURE OF SCIENTIFIC DISCIPLINES.

CLUSTER ANALYSIS OF PARTICIPATION IN SCIENTIFIC MEETINGS+

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A new method for the analysis of leadership and subdisciplinary structure of a scientific discipline is discussed. The database consists of lists of participants in international scientific meetings. Disciplinary leaders are identified by means of their frequency of participation. The subdisciplinary structure is mapped by means of cluster analysis of meetings with respect to degree of similarity. The method possesses strengths not shared by citation analysis: in addition to scientists frequently cited in the literature for their contribution to cognitive research programs, it also identifies administrative discipline builders. The method may also represent better the cognitive interests of scientists.

Introduction: Analysis of Scientific Meetings as a Scientometric Method

Scientometric studies have dealt extensively with quantitative analysis of the scientific literature, including a number of varieties of citation analysis based on the Science Citation Index. Scientometric methods are not in principle restricted to using scientific literature, however. Other measures have, in fact, been suggested, for example, co-nomination analysis.[1] Participation in scientific meetings is another possible scientometric indicator. The purpose of this paper is to demonstrate that a quantitative analysis of participation in meetings can be used as a scientometric tool, specifically for identifying leaders of a scientific discipline and its subunits, and for mapping the natural units (subdisciplines, research areas, etc.) of the discipline. We introduce this analytical tool in scientometrics as a complement to citation studies based on the scientific literature. In effect, we pursue a 'conferocentric' rather than a 'papyrocentric' approach.

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With very few exceptions, meeting participation has so far not been utilized as a database for scientometric studies. This parallels a remarkable neglect of scientific meetings as a research topic.[2] Scientific disciplines, research schools, museums, laboratories and the published literature have all been investigated in detail, whereas studies of scientific meetings (conferences, symposia, workshops, and so forth) have largely been absent from the agenda of science studies.[3]

Yet, scientific meetings have been an integral component of modern science since its inception 350 years ago. Before the mid-nineteenth century, meetings were usually organized by local or national academies and learned societies, but as a result of improved transportation systems the number of international scientific congresses have increased – from one to two meetings a year in the 1850s to about thirty a year by the end of the century.[4] For this century it is difficult to obtain comprehensive figures; however, the number of publicly announced meetings held by biomedical societies in the US grew from 467 in 1927 to 1,503 in 1961.[5]

The aims and scope of scientific meetings have also changed – they have become increasingly specialized, ranging from small workshops to national and international congresses with many parallel sessions. Today, scientific meetings provide an important arena for researchers to exchange information comparable with that of scientific literature. By analogy with scientific disciplines, meetings can also be seen as political-rhetorical units: as arenas for negotiation of what constitutes interesting research topics and for delimitation of cognitive territories. Thus, meetings provide forums both for promoters of research programs and for discipline builders.[6]

In this preliminary study we have chosen post WWII immunology to illustrate the new method. Immunology has become one of the central players in recent biomedical research[7] – we have chosen the period 1951-1972 for study, partly because one of us (AMS) has a long experience in the field, and partly because this was a period of major cognitive transition and of rapid institutionalization: many new national immunological societies were founded, chairs and departments of immunology were established, and many new journals appeared, reflecting the differentiation of immunology into many subdisciplines. The first independent international meetings on immunological research topics appeared in the early 1950s; in 1971, the triennial International Congresses of Immunology were initiated.

Selection of Meetings

By definition, a discipline under formation, as immunology in the period investigated here, has vague boundaries; hence, the identification and selection of appropriate meetings is not unambiguous. We initially made an inventory of the published conference proceedings in the collections of three major medical research libraries. We included all proceedings titles that contain the word 'immunology' (or generally 'immuno-') as well as such other central key words as 'antigen', 'antibody', 'allergy', 'transplantation', and so forth. (To these we added meetings resulting from responses to a questionnaire sent to leading immunologists throughout the world.) Well over 150 meetings were identified in our initial survey as immunological in the broadest sense, to include basic and clinical immunology, application of immunological techniques in other fields, and the border areas between immunology and other clinical and life science disciplines.

For the following scientometric analysis we have restricted ourselves to a selection of these meetings. Some were excluded for lack of published proceedings or lists of participants. (Among these are a number of significant series of informal 'workshops' which played an important part in defining the several subdisciplines of immunology, as discussed further below.) We have also excluded meetings having primarily an educational function such as summer schools, although it is sometimes difficult to draw a distinction between such meetings and research conferences, as well as meetings devoted primarily to applications, such as standardization (for example, of vaccines), the use of immunological techniques to other fields, or where immunological research problems played only a minor role in the proceedings.

Finally, we have also excluded the (semi)annual meetings of national societies, in spite of the fact that these were attended by a vast majority of immunologists in the period under investigation, since lists of participants were not always available. As a consequence of the international bias, we have probably overrepresented leaders of the field, since they are more likely than followers to attend international meetings. But since one of the aims with this work is to identify disciplinary leadership, the exclusion of meetings of national immunological societies probably is of no detrimental effect.

With all these exclusions we arrive at a list of 88 selected meetings (represented in Fig. 1).[9]

Analysis of Disciplinary Leadership

Our first aim is to determine whether the population of researchers who frequently attend meetings in the field of immunology, particularly international meetings, constitute the leading elite of the discipline. If this is the case, the identification of frequent meeting-goers might be used as a general method for identifying disciplinary elites. For each selected meeting the names of all the participants were listed and pooled to generate a master file of all participants. Usually proceedings list 'contributors', i.e., physical persons who both attend and present a paper at the meeting. Sometimes the proceedings list all persons participating in the meeting. In a few cases, however, the proceedings list authors of papers, without giving any information on whether only one or all of the authors actually participated in the meeting. In these cases we have included all authors of papers into the master matrix as 'participants'. The result is a slight overrepresentation of 'participants' who may not have physically attended the meeting. In this preliminary study we have not tried to evaluate the effect of this bias.

Since different individuals may appear under the same name or, conversely, the same individual scientist may appear under different names, the pooling procedure is not without complications. But with a few exceptions we have been able unambiguously to identify a total of 4,806 individuals that have participated in 88 immunological meetings in the period 1951-1972. The records are assembled in a master text-file in the form of a {4,806 participants; 88 meetings}- matrix.

The participation in these 88 scientific meetings is not evenly distributed. The large majority of researchers (72%, 3,480 participants) attended one meeting only in the twenty three year period. 6.5% (311) of the total number of participants attended five meetings or more. 1.6% (79) attended at least ten meetings, whereas only about 0.5% (27) attended fifteen meetings or more. One single researcher attended 39 meetings!

One might expect that the more renowned the researcher, the higher is the frequency of participation. At the high end of the frequency distribution are researchers who have attended up to around twenty meetings in the period. In fact, almost everyone of the 79 researchers that have gone to at least ten meetings are well-known to us (AMS) to be leaders in the field, either as having made important discoveries or instigated influential immunological research programs, or in the capacity of entrepreneurs or science administrators and gatekeepers.

Our subjective evaluation of the relation between high meeting-frequency and high reputation has been tested independently, by matching, for each scientist, the ranking on the meeting list with the number of citations of scientific papers. The citations of the ten most frequent meeting-goers were compared with ten randomly sampled participants that went to five meetings and ten others randomly selected from those participants that attended one meeting only (Table 1).

The result strongly suggests that the more frequently a researcher attends immunological meetings the higher is his/her scientific reputation in the field as measured by citation frequency. (We have not corrected for the fact that only the first author is listed in the Science Citation Index.) The ten most frequent meeting participants, all internationally well-known immunologists, show several thousand citation equivalents (as crudely measured in terms of text millimeters in Science Citation Index) over a twenty-five year period, whereas researchers who participated in one meeting only rarely have more than a few hundred citation equivalents.

We conclude that there is a strong correlation between frequency of participation in immunological meetings and scientific reputation in the field of immunology, for the extreme ends of the meeting frequency spectrum. (Researchers who participated in five meetings display a somewhat more varied pattern.) There are a few significant individual exceptions to this pattern, however. A few researchers who rank low on the meeting frequency scale, are nevertheless generally known as major players in the field of immunology (these may be individuals who just prefer not to go to meetings, or those who entered the field late or left it early during the period under study), and conversely, several of the frequent meeting participants are less well known (and less often cited) for their science than for their important roles in disciplinary development: governmental biomedical functionaries (for example, at the National Institutes of Health), entrepreneurial meeting organizers, 'scientific statesmen', 'gatekeepers', and so forth. E.g., #14 (Table 1) has been identified as an assistant organizer of the National Institutes of Health.

Finally, we have identified a small group of individuals who rank very high in citation frequency, but who attended only a few meetings; these are scientists famous in areas other than immunology who (for whatever reason) chose to attend a few immunological meetings. E.g., #11 (Table 1), who attended five meetings, has been identified as major scientist from another field than immunology. None of these 'outsiders' occur among the scientists attending ten or more meetings, however.

Table 1

Correlation between frequency of participation in immunological meetings and citation equivalents (Registered as column millimeters in *Science Citation Index* for the years 1955-1974)

Year	1955 – 64	1965 – 69	1970 – 74
Citation Equivalents of the Ten Most Frequent Meeting Participants (Listed in Descending Order):			
#1	2181	3094	2167
#2	985	1087	1364
#3	1002	774	824
#4	1335	1412	1652
#5	1526	1674	1253
#6	896	1481	1352
#7	654	1788	1501
#8	5332	3064	2800
#9	1035	863	2191
#10	1993	1947	1730
Citation Equivalents of a Random Sample of Scientists Participating in 5 Meetings (Listed in Arbitrary Order):			
#11	2292	2446	3882*
#12	30	119	467
#13	115	533	817
#14	-	-	31**
#15	494	464	495
#16	4	428	356
#17	206	419	598
#18	19	160	92
#19	-	21	63
#20	20	9	103
Citation Equivalents of a Random Sample of Scientists Participating in 1 Meeting (Listed in Arbitrary Order):			
#21	-	-	-
#22	-	-	322
#23	-	-	4
#24	-	18	104
#25	31	57	28
#26	19	109	181
#27	-	-	23
#28	8	34	83
#29	-	-	77
#30	-	-	-

*Person identified as major scientist from other field (see text for explanation).
**Person identified as organizer of a major research foundation (see text for explanation).

Obviously there is a continuum stretching from researchers with a high reputation attending many meetings to more marginal researchers with low reputation in the field. Nevertheless, the method employed here allows for a rapid and reliable identification of the disciplinary elite.

Classification of Immunological Meetings by Means of Cluster Analysis

Our second aim is to demonstrate how this same material can be used to identify subdisciplinary units by means of cluster analysis.[10] In our preliminary investigation meetings are compared with respect to the participation versus the non-participation of individual scientists. Two meetings are said to be more similar than two other meetings if they have more overlapping participants. A variety of similarity measures can be used – for this preliminary study we have chosen a standard Jaccard similarity measure, and a standard computer program package for cluster analysis.[11]

A first analysis was made with a {meeting; participant}-matrix reduced to the 1,326 researchers participating in two or more meetings. Each meeting from the selected list of 88 meetings was compared with every other meeting on the list. The program starts grouping together the two meetings with the highest similarity measure, and continues to group together meetings with meetings, or meetings with meeting-pairs of increasing complexity until all meetings have been grouped together in clusters. Depending upon the method of joining clusters, different procedures can be used – some of these gave uninterpretable results, others contained too much arbitrariness in clustering ('ties'); only the Average Linkage Cluster procedure gave both good resolution and non-arbitrary clustering. SAS System's Centroid and Median Cluster Analysis gave no resolution. Average Linkage, Single Linkage and Complete Linkage Analysis all gave good resolution, but only Average Linkage appeared without 'ties', i.e., points where the computer program chooses arbitrarily between two higher units with identical similarity measures. The results obtained with Single Linkage and Complete Linkage Analysis methods were not much different from results obtained with Average Linkage Analysis, however. The result of the Average Linkage Analysis is shown diagrammatically in Fig. 1.

Three other runs were made with further reduced matrices: 311 researchers participating in at least five meetings, 79 researchers that participated in at least ten meetings, and the 27 researchers that participated in fifteen or more meetings. The progressive reduction in the number of participants results in an increasing reduction in the number of meetings in the matrix; for example, only seventy-nine meetings were attended by participants belonging to the small group of scientists that attended fifteen or more meetings.

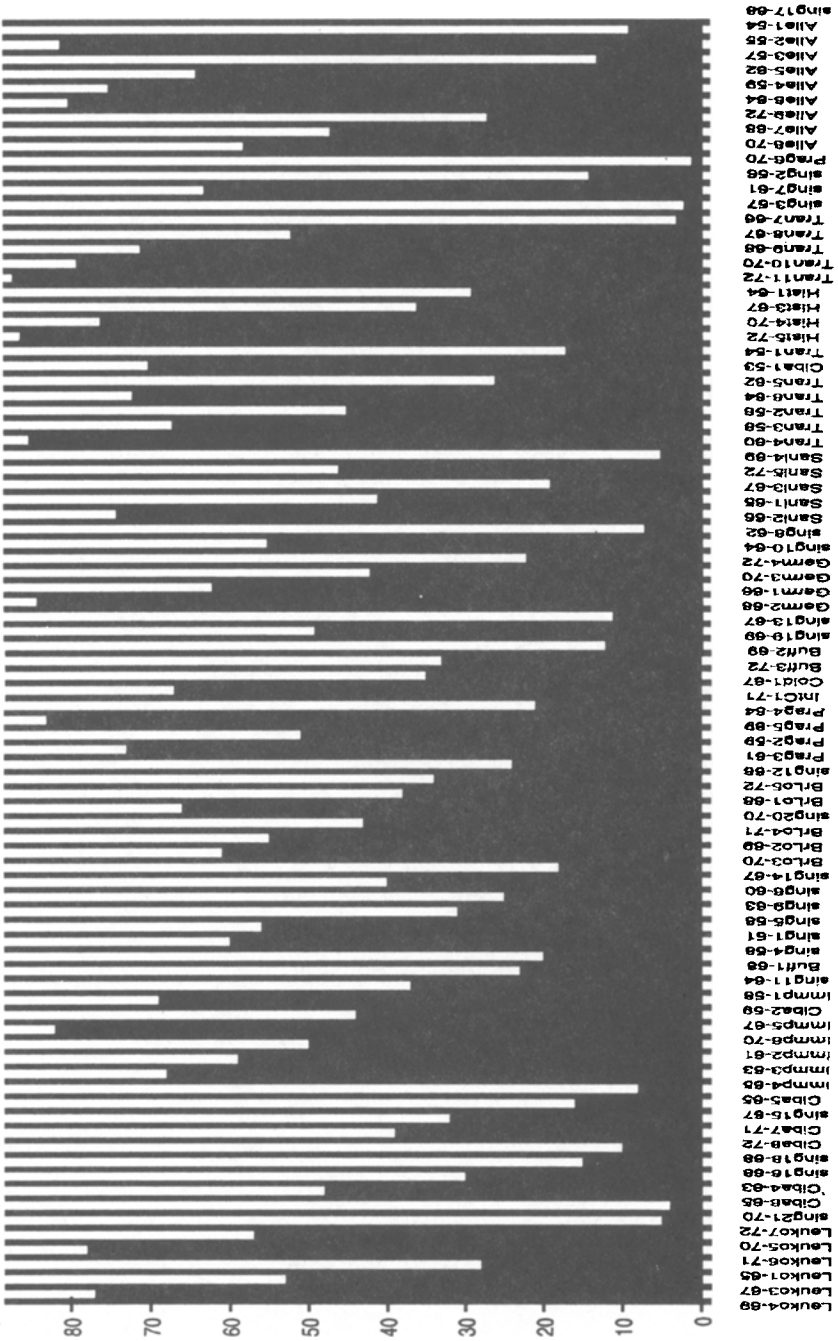

Fig. 1. Clusters of immunological meetings attended by individuals who participated in two or more meetings (n = 1,326). The cluster dendrogram should be read from top to bottom. Each vertical 'bar' represents a meeting. A cluster between two or more meetings is represented by a black area. Meetings (or clusters) that cluster close to the top are more similar with respect to overlapping attendance than meetings (or clusters) that cluster further down. For abbreviations of meetings, see text

The results of these runs show that the cluster pattern based on the participants who have attended two or more meetings is not always identical with that based on the disciplinary elite. Some meetings, for example, the Prague meetings (series *Prag*), the Immunopathology Symposia (series *Immp*), and most of the transplantation meetings (series *Tran*), have strongly overlapping attendance, irrespective whether we look at the n=1,326 population or the disciplinary elite. Other meetings, however, for example, the allergology symposia (series *Alle*), show similarities only at the n=1,326 level, while exhibiting larger dissimilarity when the comparison is based on more frequent meeting-goers. These different cluster patterns reflect the fact that meeting choices of the disciplinary elite may differ substantially from that of the bulk of immunologists. 'Meeting choice', of course, also covers the behavior of choosing to accept an invitation.

Why do meetings cluster together? To some extent, one might expect that the cluster pattern reflect generational change, i.e., that contemporary meetings will have greater overlap of participants than meetings being separated by a larger time-span. For example, generational change could be reponsible for the bimodal structure of the Sanibel Island cluster, which falls (at the n=1,326 level) into two subclusters: the years 1965-1967 (*Sani*1, *Sani*2, *Sani*3) and the years 1969-1972 (*Sani*4, *Sani*5) respectively. The generational factor is not decisive, however. The Sanibel Island subclusters could also be explained by the decisive change in cognitive content, from developmental biology problems in the three early meetings to problems dealing with the different subject of immunoglobulin classes in the later meetings. The relative minor importance of the generational factor is illustrated by the three meetings from 1956, 1961, and 1970 (*Tran*2, *sing*7 and *Tran*10) dealing with transplantation problems which cluster together (both at the n=1,326 and the n=311 levels) despite a fourteen year time-span. As a whole, the generational factor does not seem to be of much significance for the overall cluster pattern displayed in Figure 1, whereas it may be of some significance within smaller clusters.

Another possible reason for cluster formation may be that meetings held in one country share a large proportion of local participants and participants from nearby countries. For example, the cluster of the three Prague meetings on antibody formation in 1959, 1964, and 1969 (*Prag*2, *Prag*4 and *Prag*5) might be suspected to be caused by the fact that a large contingent of Eastern European researchers participated in the three meetings, a suspicion supported by the fact that another Prague meeting (*Prag*3), organized by another prominent Czech immunologist, clusters together with these meetings at the n=1,326 level. With few exceptions,

however, all participants from former Eastern European countries are excluded beyond the n=1,326 level, and the Prague meetings on antibody formation still cluster together at the n=311, n=79, and n=27 levels of analysis. Hence, the cluster of the Prague meetings on antibody formation must be due to other factors than a large regional participation – in this case most probably a combination of programmatic overlap and a deliberate invitation policy by the organizers.

We assume therefore that the main reason why meetings exhibit similarity in the cluster analysis is that they attract participants with similar scientific interests in response to the aim and program of the meeting. Thus, subdisciplines can be viewed as analogous to political parties in a multiparty democracy; meetings are comparable to party conventions, meeting participants as analogous to voters expressing party preferences, and the invited speakers represent the party nominees for office.

The Subdisciplinary Structure of Immunology – The Core Supercluster

We will now use the results of the cluster analysis for a discussion of the disciplinary structure of immunology in the period 1951-1972 as reflected by the main international meetings of the period. In this preliminary report we are not striving for stringency with respect to explanation: sometimes we will use the cluster pattern as independent variable and use our knowledge of the contemporary history of immunology to explain it; conversely we will sometimes use the cluster pattern to identify interesting disciplinary phenomena for later analysis and discussion.

We have choosen the First International Congress of Immunology held in Washington D.C. in 1971 (*IntC*1) as the reference point for further discussion. This congress was the first manifestation of the institutionalization of immunology as a scientific discipline internationally. The 1971 Congress overlaps considerably (at all four levels of analysis) with another meeting that is usually considered a seminal meeting in the contemporary history of immunology, viz., the Cold Spring Harbor meeting on Antibodies in 1967 (*Cold*1). Centered around these two meetings we identify a *core supercluster* of closely related immunological meetings, centered around problems of antibody formation and immunopathology. These include the series of Prague meetings, the Brook Lodge meeting series (*BrLo*), the Immunopathology Symposia (*Immp*), the series of meetings on germinal centers of lymphatic tissue (*Germ*), the Sanibel Island developmental immunology workshops (*Sani*), and a number of individual meetings.

Many of the participants of the Germinal Center meetings came from pathology departments – yet, cluster analysis shows no overlap between these meetings and the Immunopathology Symposia (see below), probably because the Germinal Center meetings dealt less with clinical and more with basic questions, primarily the structure and funtion of antibody producing tissues. Also belonging to the core supercluster is the series of Brook Lodge meetings (*BrLo*) organized in 1968-1972. In spite of the variety of issues treated by the five meetings, the Brook Lodge series nevertheless cluster together at all four levels of analysis (with the exception of the first meeting in the series that clusters with the Prague meetings at the n=311 through n=27 levels of analysis), confirming our subjective experience that the organizers had a fairly well-defined purpose for the meetings: drawing on a group of immunologists belonging to the most frequent meeting-goers (the elite), a small number of people were invited to the meetings.

Somewhat more distantly related (but still within the core supercluster) is a cluster formed by the series of Immunopathology Symposia (*Immp*). The immunopathology meetings cluster together at all four levels of analysis, suggesting that the immunopathologists constituted a rather closed community of scientists. Closely related to this series are two individual meetings on hypersensitivity held in 1958 (*sing*4 and *sing*5), and the Ciba meeting on 'Cellular Aspects of Immunity' (*Ciba*2). The Buffalo Convocations (series *Buff*), on the contrary, were formally organized as parts of a series but cluster analysis shows a striking dissimilarity between the individual meetings, presumably because a different topic was chosen for each meeting.

The series of workshops held on Sanibel Island (*Sani*) gathered a small number of invited participants working on developmental immunology. The first three meetings in 1965, 1966 and 1967, devoted to developmental biology, cluster together fairly well at all four levels of analysis, and close to the Germinal Center meetings. The reason why the meetings in 1969 and 1972 cluster separately is probably that they dealt with the distantly related question of immunoglobulin isotypes; and that the participants were therefore selected from a different subset of the disciplinary leaders.

In addition to these series of meetings, we can identify a number of small but important singular meetings as part of the core supercluster. For example, a small meeting on 'Regulation of the Antibody Response' in Toronto (*sing*12) overlaps considerably with the other meetings in the core supercluster, probably because it dealt with problems concerning the regulation of antibody formation. A somewhat

larger meeting on 'Cell Interactions and Receptor Antibodies in Immune Responses' in Helsinki (*sing*20) dealt with the recently discovered functional distinction between B lymphocytes (the antibody forming cells) and T lymphocytes (collaborating cells for antibody formation). Despite a large contingent of local and regional participants, this meeting has a considerable overlap with other meetings in the core supercluster, particularly at the n=27 level, suggesting that this was considered a hot topic by the core disciplinary elite at the time.

The Subdisciplinary Structure of Immunology – Clinical Clusters

All meetings discussed so far belong to a fairly heterogenous but well-delimited core supercluster. The strong overlap between meetings oriented to problems concerning basic research questions, such as the Prague meetings and the Brook Lodge meetings, and meetings seemingly oriented towards more clinical issues, such as the Immunopathology Symposia, suggests that it is difficult to make a clear distinction between basic science and certain areas of clinical immunology during the period under investigation. But the view of the immunopathological meetings as clinical is somewhat erroneous. Rather, these meetings were devoted to basic research on clinically relevant problems and the establishment of research animal models for human disease problems. Thus, clinically oriented researchers and those interested in more theoretical problems would likely go to the same meetings. The vague border between theoretical and clinical issues is not a general pattern in mainstream immunology, however, at least not in the period investigated here. A number of series and singular meetings devoted to more distinctly clinical areas fall outside the core supercluster.

The conspicuous cluster to the right of Figure 1 consists of the meetings of the Collegium Internationale Allergologicum (*Alle*) between 1954 and 1972. The diagram reflects the fact that most allergologists rarely attended other immunological meetings (and vice versa). The allergology symposia continued to be predominently clinical, and did not contribute substantially to the integration of clinical and basic theoretical issues in immunology. Reducing the matrix to the 311 participants attending five or more meetings (n=311), however, gives an interesting result: at this level of analysis the allergology meeting held in 1972 clusters with the otherwise well-defined group of immunopathology meetings. The tendency towards a greater overlap increases further with further reductions of the matrix, particularly at the n=27 levels; we interpret this as a reflection of the discovery in the late 1960s of the

antibody (IgE) responsible for allergic diseases, and of the beginning elucidation of the immunophysiological mechanisms of allergic reactions, leading to an increasing, albeit still sporadic, participation of the mainstream leaders at these meetings.

Another fairly well-defined main clinical cluster outside the core supercluster is composed of the three series of transplantation meetings held in the period: the New York Academy of Science series between 1954 and 1966, the international transplantation congresses held from 1967, the series of Histocompatibility Workshops organized from 1964 and onwards. The New York Academy of Science meetings clusters at the n=1,326 level, but shows greater dissimilarity at the disciplinary elite level. This predominantly US- dominated meeting series was succeeded by the more European-dominated International Congresses of the Transplantation Society that clusters together through all four levels of analysis.

The two transplantation meeting series overlap considerably with the Histocompatibility Workshops (*Hist*). This series of small workshop-like meetings was specifically technical in orientation. The histocompatibility series cluster together when the whole population of immunologists is considered (n=1,326), but display somewhat larger dissimilarity with respect to overlapping participation of the disciplinary elite. The close overlap with the transplantation meetings might be explained by the fact that graft rejection, the leading topic of interest to transplanters, was early shown to be due to the histocompatibility antigens dealt with in the Histocompatibility Workshops.

A few singular meetings also overlap with this transplantation cluster. For example, the Ciba Foundation meeting on 'Preservation and Transplantation of Normal Tissues' (*Ciba*1) was the first international transplantation meeting in this time period. Likewise, the meeting on 'Mechanisms of immunological tolerance' organized in Czechoslovakia in 1961 (*Prag*3) reflects the intimate relationship between research on immunological tolerance and the emerging immunobiological basis for transplantation.

Yet another well-defined cluster outside both the core supercluster and the two major clinical clusters is constituted by the series of annual Leucocyte Culture conferences (*Leuko*) originally concerned predominently with leukocyte structure and physiology. The series shows very little overlap with all other meetings at the n=1,326, n=311, and even n=79 levels of analysis, indicating that researchers specialized in leucocyte culture studies did not mix with other immunologists, despite the fact that this eventually became an area of immense importance for immunological research. The disparity at the n=27 level is not surprising, since major researchers in immunology would not be expected to restrict their participation to these predominantly technical meetings.

Discussion

The new scientometric approach presented here can be used in identifying scientific leaders and in mapping the subdisciplinary structure of the discipline of immunology in the post WWII period. Generalizing from the findings reported in this paper, we predict that the method will be especially useful in the mapping of emerging new disciplines.

The method shares one strength with co-citation analysis,[12] viz., that the outcome of the analysis reflects the scientists' own behavior. But the method also possesses strengths not shared by other forms of citation analysis. In addition to scientists who are cited (or co-cited) frequently in the literature because of their contribution to cognitive research programs, it identifies also discipline builders and institutionalizers, i.e., people, who, are founders of disciplines rather than promotors of cognitive research programs – those administrators and meeting organizers whose scientific contributions may have been less important than their organizational efforts.[13] For example, several of those who rank high on the frequency scale do so not as leading scientists, but rather as leading meeting organizers.

Further, the method adjusts for those frequently cited scientists from other disciplines and specialties who may have touched the discipline briefly, but whose citations from work in the other discipline might have made them appear more important in this one than is justified. Because scientists probably do not go to meetings that does not interest them, the method may also better represent the cognitive interests of scientists and thus corrects for one of the major drawbacks of citation analysis methods, including co-citation analysis, viz., that citations do not necessarily reflect cognitive interests.[14] Finally, the method can be used for historical periods not yet covered by the retrospective publication of *Science Citation Index*.

Since this is a preliminary report, a few caveats should be mentioned. First, the method involves some initial manual labour in finding meeting proceedings and coding listings of participants. Second, in excluding from the study the meetings of national immunological societies we assume that the data base may underrepresent junior scientists or those who were attached only transiently with immunology. Conversely, since the analysis of disciplinary leaders in terms of meeting attendance excludes those who left the field early or entered it, the disciplinary elite may be somewhat underrepresented. Finally, the cluster analysis procedure used has a minor procedural defect: When a given meeting is clustered together with certain other meetings, it is preempted from further comparison with all other meetings.

We should also indicate some of the paths that future research in this field might follow. The defects in the cluster analysis procedure have to be overcome, e.g., by inspecting the similarity indices between each meeting and *all* others, in which case these additional relationships emerge. The data base could also be expanded in several ways: Since lists of participants usually contain information about departmental affiliation and national origin, it may be possible to analyze the extent to which departmental or institutional affiliation changes with time and among subdisciplines, and how subdisciplines may be based upon different departmental contexts. Second, the individual scientist's role in the meeting (as a keynote speaker, self-volunteered presenter, or passive attendee) may tell much about the scientist's standing in the community. Third, the time window should be expanded backward and forward to illuminate the structural changes in immunology throughout the century.

The selection of meetings might also be expanded to include national meetings, significant unpublished meetings, and immunological sessions within other meetings, such as international congresses of microbiology, hygiene, medicine, and pathology. Finally, the database might be expanded to include information about keywords in the titles of meetings and in the papers presented. This would permit a more precise tracking of the cognitive developments within the discipline.

After these procedural corrections and expansions, the strength of the method suggested here should be evaluated by comparison with other scientometric methods[15] and with respect to its usefulness for the study of modern and contemporary history of science.

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