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Disciplinary History of Science - The Case of Immunology, 1951-72

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• **ABSTRACT**

To handle the enormous amount of sources in modern and contemporary science, the historian can use different quantitative methods, particularly varieties of citation analysis. So far, all these methods have been based on publication data. Taking as its point of departure the fact that meetings constitute a pervasive, yet neglected, aspect of science, this paper introduces analysis of participation in scientific meetings. The strength of this new prosopographical method is illustrated by an analysis of international immunological meetings in the period 1951–72. Frequency of participation in meetings seems to be correlated to professional standing in immunology. By means of cluster analysis of participation data, the subdisciplinary structure and dynamics of immunology can be reconstructed.

Participation in Scientific Meetings: A New Prosopographical Approach to the Disciplinary History of Science – The Case of Immunology, 1951–72

Thomas Söderqvist and Arthur M. Silverstein

Scientific Meetings as a Research Topic

Scientific meetings constitute a pervasive and integral part of science. They have been an integral component of modern science since its inception in the seventeenth century, when the Lincei, the *Investiganti*, the *Cimento* and the Royal Society met to spread knowledge among their participants and to disseminate the new knowledge further with the publication of *Transactions* and *Proceedings*. Before the mid-nineteenth century, meetings were usually organized by local or national academies and learned societies, but as a result of improved physical transportation systems the number of international scientific congresses increased – from one to two meetings a year in the 1850s to about 30 a year by the end of the century.¹ Comprehensive figures for this century

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are more difficult to obtain. For example, the number of publicly announced meetings held by biomedical societies at all levels in the USA grew from 467 in 1927 to 1503 in 1961.² Attendance has grown even more conspicuously; for example, the annual meetings of the Federation of American Societies for Experimental Biology grew from approximately 2000 participants in 1942 to over 15,000 in 1963.³

Parallel to the growing specialization of the sciences, the aims and scope of scientific meetings have changed; they have become increasingly specialized too, ranging from small 'by invitation only' workshops to national and international congresses with mini-symposia and many parallel sessions. Today meetings not only provide arenas where researchers can exchange information about new theories, data and techniques. By analogy with scientific disciplines, they can also be seen as political-rhetorical units – arenas for negotiation of what constitutes interesting research topics, for delimitation of cognitive territories, and for distribution of scientific status and roles within the disciplinary hierarchy.⁴

Given the pervasive role of meetings in science throughout modern history, it is astonishing that they have been rather neglected as an independent topic of inquiry, both by sociologists and historians of science. Whereas scientific disciplines, research schools, museums and laboratories have been scrutinized in detail, studies of scientific meetings (conferences, symposia, workshops and so forth) have, to a large extent, been absent from the agenda of science studies. True, a few communication and information science scholars have studied the importance of meetings for informal scientific communication,⁵ and as means for the early detection of new trends in science and technology.⁶ But with few minor exceptions sociologists of science have paid very little attention to scientific meetings as compared to an overwhelming interest in the published literature, particularly journals. Early sociologists of science did not mention the phenomenon of meetings or did so only in passing – for example, Diana Crane, in her seminal *Invisible Colleges*, restricts the discussion of the diffusion of knowledge in scientific communities to the scientific literature.⁷ Recent sociologists of scientific knowledge have not paid much attention to meetings either – the journal *Social Studies of Science* has not carried a single paper dealing with the topic since its start in 1971.⁸

Historians of science have paid somewhat more attention to

meetings. However, it is difficult to find systematic studies of the role and importance of scientific meetings in the history of science, or studies of the role of meetings in science, in the formation of scientific disciplines and research areas, and so forth. Meetings have been utilized as ‘mirrors’ of scientific development,⁹ programmes and proceedings of scientific meetings have sometimes been used as source material for institutional and disciplinary histories of science,¹⁰ and histories of scientific societies regularly draw on studies of their meetings.¹¹ But except for a few quantitative studies of meetings of scientific societies,¹² historians of science as a whole have rarely made meetings or series of meetings an independent topic of inquiry.¹³

The phenomenon of meetings deserves the attention of scholars in science studies for a variety of reasons. In this paper we have singled out one specific topic for discussion – namely, the use of a prosopographical analysis of the participants of meetings for understanding the establishment and dynamics of scientific disciplines and research areas. We ask questions such as: can we use participation in meetings to identify leaders of the discipline and its subunits? Which are the natural units (subdisciplines, research areas and the like) in the discipline? How are these units related to each other? Can we map disciplinary dynamics – for example, can we determine how and when peripheral research areas with their own research programmes join the ‘mainstream’ of the discipline?

These and similar questions are akin to the kind of questions usually asked in prosopographical and scientometric studies. Data from memberships of scientific societies have been used in prosopographical studies,¹⁴ but no study has focused on similar data from scientific meetings. Scientometrical studies have dealt extensively with quantitative analysis of authors of scientific articles, including different varieties of citations analysis,¹⁵ and one recent study has utilized word distributions in conference papers as a tool for historical research.¹⁶ So far, however, participation in scientific meetings has not been used as a tool in historical studies. Hence, with this paper, we introduce meetings and their participants as a new type of database for prosopographical studies for historical purposes.

We have chosen the field of immunology to illustrate these possibilities, in part because we have earlier experience in this

field, but also because immunology has become one of the central players in recent biomedical research.¹⁷ We have chosen the period 1951–72 for study primarily because this was a period of major and radical cognitive transition in the field of immunology,¹⁸ and also a period of rapid institutionalization – many new national immunological societies were founded (there are now 41 in the International Union of Immunological Societies);¹⁹ many new journals (now numbering well over 50) appeared, reflecting the differentiation of immunology into many subdisciplines; chairs and departments of immunology were established; and finally, in 1971, the triennial International Congresses of Immunology were initiated. Furthermore, the number of meetings in this period is large enough to permit a quantitative analysis to illustrate the new prosopographical tool proposed in this paper.

Immunological Meetings 1951–72: Taxonomic Aspects and Selection Criteria

By definition, a discipline under formation, as was immunology in the period investigated here, has broad and vague boundaries. Hence, the identification and selection of appropriate meetings is not entirely unambiguous. We initially made an inventory of the published conference proceedings in the collections of three major research libraries: the Welch Library of the Johns Hopkins Medical School in Baltimore, the Danish Science and Medical Library in Copenhagen, and the library of the Basel Institute of Immunology. As a first approximation, we included all proceedings titles that contain the words ‘immunology’ (or generally ‘immuno-’), as well as such other central key words as ‘antigen’, ‘antibody’, ‘allergy’, ‘transplantation’, ‘histocompatibility’ and so forth. To these we added meetings mentioned in responses to a questionnaire sent to leading immunologists throughout the world.²⁰ Well over 150 meetings were identified in our initial survey as immunological in the broadest sense, to include basic and clinical immunology and the border areas between immunology and other clinical and life science disciplines.

There is a great variation in organizational structure and alleged aim of the immunological meetings employed in this study, which

itself deserves future attention. These variations may depend on size, on exclusivity of participation, on the avowed intent of the organizers and on whether they are isolated meetings or members of a distinct series. We shall give here only a few preliminary examples of these variations, based on our general knowledge of the area, since the taxonomy of scientific meetings appears to represent an important, if thus far relatively unexplored, area of interest to science studies.

A major feature of meetings is whether they stand alone or are part of a series. Only about one quarter of the meetings included in this study are singular. Meetings most frequently result from the identification of an important or emerging research area by a governmental or private institution, a scientific society or by entrepreneurial scientists themselves. They are then organized, usually with outside financial support, to record and to publicize progress in the field, and to provide publicity for the scientists or their institutions. Among the meeting series, for example, are the transplantation meetings of the New York Academy of Sciences and its heir, the Transplantation Society, the Germinal Center series, the Leukocyte Culture Conferences and the Histocompatibility Workshops, all devoted to the course of progress within a specific subdiscipline of the science. On the other hand, there are the Ciba Foundation, the Sanibel Island or the Brook Lodge series, within which each separate meeting explored in great depth a different important area of the discipline. By contrast, the (roughly) decennial Cold Spring Harbor series, the annual meetings of National Societies and the triennial International Congresses summarized the status of the entire discipline in its most important aspects.

With respect to size, the Ciba, Sanibel Island and Brook Lodge meetings often involved only 15–30 participants from among those scientists considered internationally noted in the field of interest,²¹ sometimes with experts from outside the field for interdisciplinary stimulus. At the next level are such meetings as the Prague series, the Germinal Center series and the Histocompatibility Workshops, which had invited presentations and a selected list of participants, usually numbering fewer than 100. Above these were such meetings as the Buffalo Convocations, the New York Academy of Sciences transplantation meetings, the Cold Spring Harbor meeting and the Collegium Internationale Allergologicum

series, whose audiences might number in the hundreds. Finally, there are the National Society meetings (especially in the United States) and the International Congresses, open to the entire world of immunology, with audiences in the thousands. It should be noted, as yet another structural characteristic of meetings, that whereas most of those on the list involve single sessions or series of sessions without competition, recent national society meetings and the International Congresses have reflected the great subdivisions within the larger field by holding multiple simultaneous sessions of minisymposia, workshops and poster displays.²²

The various meetings might also be classified with reference to different avowed aims.²³ Thus, the pronounced aim of the Ciba, Sanibel Island and Brook Lodge meetings was to gather together the world leaders for informal discussion of a given area, to explore in depth its recent developments and especially its theoretical and practical implications. The Histocompatibility Workshops were initially designed to promote the standardization of reagents and techniques in a technically complicated young field, but soon broadened their scope. The Germinal Center, Leukocyte Culture, and Transplantation series of meetings were intended both to record progress in a subdiscipline as well as to advertise the area broadly. The Buffalo Convocations and Collegium Internationale Allergologicum series were meant not only to record progress in the field, but also to educate their respective memberships on that progress. Finally, the Cold Spring Harbor and International Congress meetings were intended to provide the milestone markers of progress in the entire discipline for all to see.

Exclusivity is yet another variable in the evaluation of meeting structure and function. Thus, many of the smaller meetings (for example, the Ciba meetings, the Brook Lodge series, and many of the early workshops) were by invitation only, the list chosen by the organizers. At an intermediate level are the Prague series, the Germinal Center series, the Buffalo Convocations and many of the individual symposia, to which the speakers were invited from among leaders of the field, but the audience might be open to all comers. Finally, the National Society meetings and International Congresses represent a mixture, in which the symposia are presented by invited speakers from among leaders in the field, but poster- and workshop-session presenters are self-selected (although their abstracts may be screened by a programme committee).

Selection Criteria

Our discussion so far serves mainly to draw attention to the taxonomic aspect of meetings. The major aim of this paper, however, is to subject immunological meetings and the participants of these meetings to a prosopographical and scientometric analysis. The main idea behind our analysis is that a quantitative analysis of participation in meetings might provide information about the structure and dynamics of the community of immunologists during the period of progressive disciplination of the field of immunology. To pursue this aim, we have analyzed all individual participants in a large number of immunological meetings from the period 1951–72.

For practical reasons, we have restricted ourselves to a selection of the meetings discussed in the preceding section. Some of these meetings were immediately excluded for lack of published proceedings or lists of participants.²⁴ 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 later.²⁵ We have also excluded all 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. Further, we have 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. Also excluded were meetings devoted primarily to standardization (for example, of vaccines); to applications of immunological techniques to other fields; or where immunological research problems played only a minor role in the proceedings.²⁶

With these exclusions, we ended with a list of 88 selected meetings (see Appendix). It should be noted that we are aware that we have not yet identified all of the meetings applicable to a study of this type, but feel that our current sample of 88 meetings represents a good first approximation. 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.

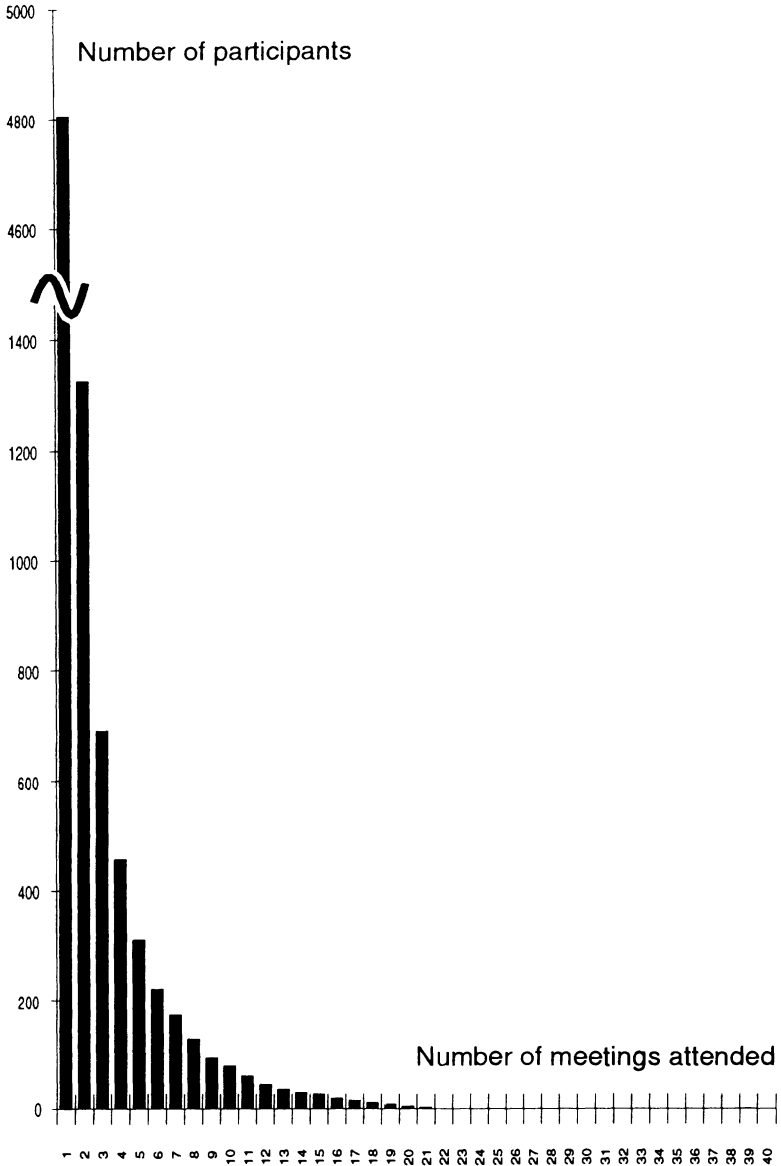
The Disciplinary Leadership in Immunology, 1951–72

We first wished to determine whether the population of researchers who frequently attend meetings in the field of immunology, particularly international meetings, constitute the leading élite of the discipline. If this is the case, the identification of frequent meeting-goers might be used as a method for mapping the disciplinary élite. For each selected meeting, the names of all the participants were listed and pooled to generate a master file of all participants.²⁷ The pooling procedure is not without complications, since different individuals may appear under the same name, or vice versa (for example, is F. Albert identical with Fritz H. Albert?), but with very few exceptions we have nevertheless been able unambiguously to identify a total of 4806 individuals who have participated in 88 immunological meetings in the period 1951–72. The records are assembled in a master text-file in the form of a {4806 participants; 88 meetings}-matrix.

As expected, the participation in scientific meetings is by no means evenly distributed. The cumulative frequency distribution is shown in Figure 1. The large majority of researchers (72%, 3480 participants) attended one meeting only in the twenty-three year period; 6.5% (311) of the total number of participants attended at least five meetings; 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 higher the frequency of participation, the more renowned is the researcher. At the high end of the frequency distribution are researchers who have attended up to around twenty meetings in the period 1951–72. In fact, almost every one of the 79 researchers who have gone to at least ten meetings are known to us (as historians of contemporary immunology) to be leaders in the field, either as having made important discoveries or instigated influential immunological research programmes, or in the capacity of entrepreneurs or scientific gatekeepers. It may be appropriate to point out here that several of those who figure prominently on the frequency list do so not as leading scientists,

FIGURE 1
Cumulative Distribution of Frequency of Participation in Immunological Meetings
1951-72



but rather as leading meeting organizers – that is, as discipline builders rather than promoters of cognitive research programmes.²⁸ In addition, meeting organizers might frequently invite their ‘favourite scientists’ to participate, quite apart from objective scientific considerations. Again, a leading scientist invited to meetings will often take along a favoured colleague or student who might otherwise not have been invited.

We have made a crude test of our subjective evaluation of the relation between high meeting-frequency and high reputation independently, by matching the ranking on the meeting list with another generally accepted indicator of scientific reputation, the number of citations of scientific papers. The citations of the ten most frequent meeting-goers were compared with ten randomly-sampled participants at five meetings and ten others randomly selected from those participants that attended one meeting only. The result strongly indicates that the more frequently researchers attend immunological meetings, the higher is their scientific reputation in the field. The ten most frequent meeting participants (attending 18 meetings or more) show some 4000–5000 citation equivalents over a 25-year period, whereas researchers who participated in one meeting only rarely have more than a few hundred citation equivalents. Researchers who participated in five meetings display a somewhat more varied pattern.

Hence, we suggest 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.²⁹ There are a few significant individual exceptions to this pattern, however. On the one hand are a few researchers who rank low on the meeting frequency scale, but are generally known as major players in the field of immunology.³⁰ 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. Conversely, several of the more 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. Finally, we have identified a small group of individuals who rank very high in citation frequency, but who attended only a single meeting or two; these are scientists famous in fields other than immunology who

for whatever reason chose to attend an immunologically-oriented meeting.

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 – hence, the borderline between a disciplinary élite and a non-élite of immunologists cannot be drawn sharply. For the following cluster analysis, however, we distinguish four populations of immunologists: a large group of ‘followers’ that consists of those attending fewer than five meetings; the major professionals in the field consisting of those attending five or more meetings; a disciplinary élite consisting of those attending ten or more meetings; and a ‘core élite’ consisting of those attending fifteen or more meetings.

Classification of Immunological Meetings with Respect to Overlapping Participation

In the preceding section, we have shown how data about the participation in immunological meetings can be used to identify leaders in the discipline of immunology. In this section we will demonstrate how this same material can be used to identify sub-disciplinary units by means of cluster analysis. After a description of the cluster technique, we present the results of the analyses at four different population levels, and compare the quantitative results with a qualitative evaluation of the immunological meetings.

Cluster analysis is a widely used method for taxonomic purposes in biological classification, linguistics, sociology and psychometrics.³¹ It has been used as a routine method for scientometric purposes, particularly in co-citation analysis,³² in which articles are classified in pairs on the basis of the similarity between their reference lists. In this 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,³³ and a standard computer program package for cluster analysis.³⁴

A first analysis was made with a {meeting; participant}-matrix

reduced to the 1326 researchers participating in at least two meetings. Each meeting from the selected list of 88 meetings (Appendix) 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.³⁵ The result is shown diagrammatically in Figure 2. This particular mode of representation, which differs from standard representations of cluster analyses, was chosen to allow the reader to identify each individual meeting in the diagram.

As seen from Figure 2, the 88 meetings fall into a hierarchy of clusters. The diagram should be read from right to left. Each 'bar' represents a meeting. A cluster between two or more meetings is represented by a black area. Meetings (or clusters of meetings) that cluster close to the right are more similar with respect to overlapping attendance than meetings (or clusters) that cluster further to the left. For example, meetings *Leuko4–69* and *Leuko3–67* cluster together at similarity level 77, and this pair in turn clusters with meeting *Leuko1–65* at similarity level 52. These three meetings together cluster with the group formed by meetings *Leuko6–71*, *Leuko5–70* and *Leuko7–72*, and all together the six meetings constitute the leukocyte culture cluster at the top of the figure.

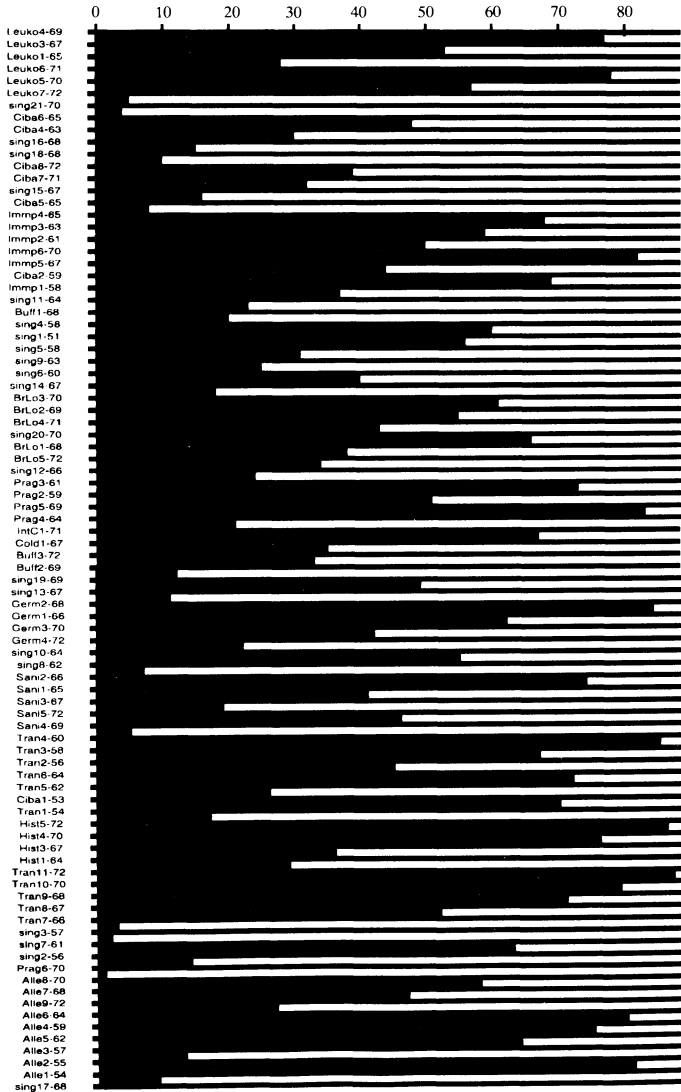
The cluster pattern based on the participants who have attended two or more meetings is not necessarily identical with that based on the disciplinary élite. To test this assumption, three other runs were made with further reduced matrices: 311 researchers participating in at least five meetings; 79 researchers participating in at least ten meetings; and the 27 researchers who participated in fifteen or more meetings.³⁶ Some meetings – for example, the Prague meetings (series *Prag*), the Immunopathology Symposia (series *Imm*), most of the Transplantation meetings (series *Tran*) and the first three Sanibel Island meetings (*Sani1*, *Sani2*, *Sani3*) – have strongly overlapping attendance, irrespective whether we look at the $n=1326$ population or the disciplinary élite. Other meetings – for example, the Allergology symposia (series *Alle*) –

show similarities only at the $n=1326$ 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 sometimes differ substantially from that of the bulk of immunologists – for example, in the case of allergology, elite scientists, who are prone to be more specialized, would probably neither be invited to, nor voluntarily attend, all of the allergology meetings, since each one was devoted to a different subdivision of the overall field. But the clinical allergologist public, being generalists, would presumably be less discriminating in their meeting choice.³⁷

Why do meetings cluster together – that is, why do researchers go to the same meetings? A comprehensive answer to this question would necessitate recourse to a sociological analysis, for example, of the rules governing the choices made by individual scientists. Within the context of this preliminary analysis, however, a few interesting observations can be made. It would seem obvious that, as a first approximation, meetings will be related to one another to the extent that their topical contents overlap, and that scientists will attend those meetings that deal with their areas of interest and expertise. But two other potential contributors must first be ruled out – temporal and geographic bias. To some extent, one might expect that the cluster pattern reflects generational change – that is, that contemporary meetings will have a greater overlap of participants than meetings separated by a larger time-span. So, the allergology meetings fall into subclusters that probably reflect generation change. The generational change could also be responsible for the bimodal structure of the Sanibel Island cluster, which falls (at the $n=1326$ level) into two subclusters – the years 1965–67 (*Sani1*, *Sani2*, *Sani3*) and the years 1969–72 (*Sani4*, *Sani5*), respectively. Likewise, the leukocyte culture meetings (series *Leuko*) fall into two time groups. The generational factor is not decisive, however. The Sanibel Island subclusters, for example, can 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 relatively minor importance of the generational factor is illustrated by the three meetings from 1956, 1961 and 1970 (*Tran2*, *sing7* and *Tran10*) dealing with transplantation problems: they cluster together (both at the $n=1326$ and the $n=311$ levels), despite a fourteen year time-

FIGURE 2

Dendrogram Showing Clusters of Immunological Meetings Attended by Individuals Who Participated in Two or More Meetings ($n=1326$)



Note: The dendrogram should be read from right to left. Each '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 right are more similar with respect to overlapping attendance than meetings (or clusters) that cluster to the left. For example, meetings *Leuko4-69* and *Leuko3-67* at the top of the figure cluster together at similarity level 77 and this pair in turn clusters with meeting *Leuko1-65* at similarity level 52. These three meetings together cluster with the group formed by meetings *Leuko6-71*, *Leuko5-70* and *Leuko7-72*, and all together the six meetings constitute the leukocyte culture cluster. See text for further explanation.

span. As a whole, the generational factor does not seem to be of much significance for the overall cluster pattern displayed in Figure 2, 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 and regional participants. For example, on first inspection, one might suspect that the cluster of the Prague meetings on antibody formation in 1959, 1964 and 1969 (*Prag2*, *Prag4* and *Prag5*) reflects the fact that a large contingent of Czech and other Eastern European researchers participated in the three meetings – a suspicion supported by the fact that another Prague meeting (*Prag3*), organized by another prominent Czech immunologist, clusters together with these meetings at the $n=1326$ level. With few exceptions, however, all regional participants are excluded beyond the $n=1326$ 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 conscious invitation policy by the organizers.

Ruling out contemporaneity and regional bias as major causes of clustering, we assume that the main reason why meetings exhibit similarity in the cluster analysis is that they attract participants with similar interests in response to the aim and programme 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, 1951–72

With the cluster analysis as our point of departure, we will now discuss the disciplinary structure of immunology in the period 1951–72, as reflected by the main international meetings of the period. It should be noted that 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 chosen the First International Congress of Immunology held in Washington, DC, in 1971 (*IntC1*), as the reference point for further discussion. The congress, suggested in the mid-1960s and formally decided upon by the newly formed International Union of Immunological Societies, was the first manifestation of the institutionalization of immunology as a scientific discipline internationally.³⁸ It was a comprehensive meeting: its 15 sessions and 84 workshops were devoted to all possible aspects of immunology. Accordingly, we consider all other meetings as being more or less peripheral in relation to this reference point in the disciplinary process.

The 1971 International Congress overlaps considerably (at all four levels of analysis) with another meeting that has risen to legendary status in the historical consciousness of present immunologists – namely, the Cold Spring Harbor meeting on Antibodies in 1967 (*Cold1*) – thus supporting the view that the antibody problem was the central issue in immunology in the 1960s. Centred around these two meetings, we can identify a fairly heterogeneous but clearly delimited *core supercluster* of closely related immunological meetings, including 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 (*Sani1*, *Sani2*, *Sani3*), and a small number of individual meetings.

The similarity of the Prague meetings and the two reference point meetings supports the view that the mechanism of antibody formation was at the centre of scientific interest among immunologists in the late 1950s and throughout the 1960s. Also within the core supercluster is a cluster consisting of the series of meetings on germinal centres of lymphatic tissue. A short glance at the list of participants shows that many came from pathology departments. Yet the cluster analysis shows no overlap between these meetings and Immunopathology Symposia (see later), probably because the Germinal Center meetings dealt less with clinical and more with basic questions, primarily the structure and function of antibody-producing tissues.

Also belonging to the core supercluster is the series of Brook

Lodge meetings (*BrLo*) organized in 1968–72. 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). This confirms our feeling 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 élite), a small number of people were invited to the meetings.

Somewhat more distantly related (but still within the core supercluster of immunological meetings) is the cluster formed by the series of Immunopathology Symposia (*Imm*), organized from 1958 and onwards. Before 1958 the modest activity in immunopathological research had been presented within the context of other meetings, such as the annual meetings of the American Association of Pathologists and meetings of different clinical disciplines, such as haematology. The immunopathology meetings cluster together (and with a meeting outside the series, namely, the Ciba meeting on ‘Cellular Aspects of Immunity’ [*Ciba2*], where Burnet’s clonal selection theory and Simonsen’s graft-versus-host experiments, two major events in the cognitive development of post-World War II immunology, were discussed for the first time)³⁹ 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 (*sing4* and *sing5*). Perhaps one of the best indicators of the major cognitive shift from immunochemistry to immunobiology during this period is the increasing number of meetings on such biomedical topics as hypersensitivity, immunopathology, autoimmunity and so forth. This was reflected also in the increasing attention paid to these subjects at the annual meetings of pathologists, haematologists and neurologists.

The series of workshops held on Sanibel Island (*Sani*) was initiated in 1965 and supported by the National Institute of Child Health and Human Development: they 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. A small (28 selected participants) meeting on 'Regulation of the Antibody Response' in Toronto (*sing12*) 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 (89 participants) meeting on 'Cell Interactions and Receptor Antibodies in Immune Responses' in Helsinki (*sing20*) 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 (almost half of them came from Finland and nearby Sweden) 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 very hot topic by the core disciplinary elite at the time. Two symposia at Rutgers University – 'Immunochemical Approaches to Problems in Microbiology', organized in 1960 (*sing6*), and 'Nucleic Acids in Immunology', organized in 1967 (*sing14*) – apparently drew on a similar constituency of immunologists (although both fall outside the core supercluster at the $n=27$ level). The two meetings on gammaglobulins, organized in Sweden (Stockholm 1967 and Lund 1969, *sing13* and *sing19*, respectively), that cluster together up to the $n=79$ level, nevertheless show different affinities to the other meetings of the core supercluster, depending on the level of analysis.

The Buffalo Convocations (series *Buff*) 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. They were attended by a large contingent of local and regional participants from Buffalo and other parts of New York State (the first meeting gathered over 300 researchers), and a small number of invited internationally leading immunologists, giving the impression that the main aim of the meetings was to put Buffalo on the world map of immunology. At the $n=1326$, $n=79$ and $n=27$ levels the Buffalo meeting in 1968 clusters (albeit weakly) together with the Immunopathology Symposia, whereas the Buffalo meetings in 1969 and 1972 show much more varied relationships with other meetings.

More Peripheral Clusters

All the meetings discussed so far belong to the heterogeneous but well delimited core supercluster centred around problems of antibody formation and immunopathology. 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 to view the immunopathological meetings as 'clinical' is questionable. Rather, these meetings were devoted to basic research on clinically relevant problems and the establishment of research animal models for these human disease problems, such as immune complex disease, autoimmunity (including haematology) and the basic mechanisms of allergic diseases. Thus, clinically-oriented researchers and those interested in the theoretical problems of antibody formation, T/B-cell interaction, immunopathogenetic mechanisms, and so forth, would likely go to the same meetings.

The vague border between theoretical and clinical issues is not a general pattern in immunology, however, at least not in the period investigated here. A number of series and singular meetings devoted to other clinical areas fall outside this core supercluster. The conspicuous cluster to the right of Figure 2 consists of the nine symposia of the Collegium Internationale Allergologicum (*Alle*) between 1954 and 1972. Historically, allergy research emerged as a distinct clinical discipline during the early twentieth century, when chemical studies of antibody–antigen reactions gradually took over mainstream immunology, and this separation continued well into the postwar era.⁴⁰ The diagram reflects the fact that most allergologists rarely attended other immunological meetings (and *vice versa*). The allergology symposia continued to be predominantly clinical, and did not contribute substantially, if at all, to the integration of clinical and basic theoretical issues in immunology.⁴¹ It should be noted that this insulated character of allergologists is independent of generational shifts. The allergology cluster falls into three subgroups: the two symposia of 1954 and 1955 (*Alle1* and *Alle2*); the four symposia of 1957–64

(*Alle3*, *Alle4*, *Alle5*, *Alle6*); and the three symposia of 1968–72 (*Alle7*, *Alle8*, *Alle9*) – a distribution that probably reflects an intra-allergological generational shift in participants over time. But this generational shift occurs within a closed circle of allergologists and does not involve any significant overlap between allergologists and other areas of 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 emerging elucidation of the immunophysiological mechanisms of allergic reactions. Thus, we see the beginnings of the integration of allergy research into mainstream immunology, a process reflected by the increasing, albeit still sporadic, participation of the mainstream leaders at these meetings.

Another well-defined main clinical cluster outside the core supercluster is composed of the 15 or so transplantation meetings held in the period: the series of transplantation meetings arranged by the New York Academy of Sciences between 1954 and 1966; the international transplantation congresses held from 1967; the series of Histocompatibility Workshops organized from 1964 onwards; and a few singular meetings (*sing7*, *sing18*). The New York Academy of Sciences meetings were started by plastic surgeons working on skin transplantation. The series clusters at the $n=1326$ 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.

Together, the two transplantation series overlap considerably with the Histocompatibility Workshops (*Hist*). This series of small workshop-like meetings was specifically technical in orientation.⁴² The series cluster together when the whole population of immunologists is considered ($n=1326$), 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. The Ciba Foundation meeting on 'Preservation and Transplantation of Normal Tissues' (*Ciba1*) was the first international transplantation meeting in this time period. The meeting on 'Mechanisms of Immunological Tolerance' organized in Czechoslovakia in 1961 (*Prag3*) reflects the intimate relationship between research on immunological tolerance and the emerging immunobiological basis for transplantation.

Yet another well-defined cluster is constituted by the series of annual Leukocyte Culture conferences (*Leuko*) originally concerned predominantly with leukocyte structure and physiology. The series shows very little overlap with other meetings at the $n=1326$, $n=311$ and even $n=79$ levels of analysis, indicating that researchers specialized in leukocyte 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

In this preliminary paper, we present a new approach to the prosopographical analysis of a scientific discipline, using as a model the field of immunology during a period of a major conceptual and institutional transition between 1951 and 1972. This was when a significant cognitive shift occurred, from chemical to biomedical concerns, and with a rapid institutionalization with respect to chairs, journals, departments, societies and international meetings. Material for the analysis is presented by the lists of participants collected from 88 published international meetings on various topics in immunology held during that period. A master file of 4806 names was thus generated; of these, 1326 participated in two or more meetings, 311 in five or more, 79 in ten or more, and 27 in fifteen or more meetings. The statistical program employed identifies the major meeting-goers in the field,

and by cluster analysis the interrelationships among the various meetings in terms of overlapping attendance are demonstrated.

This new prosopographical approach, like citation analysis, is useful in identifying the scientific leaders in a discipline, and in the several subdisciplines attached to the mainstream core. But it possesses several additional strengths not shared by citation analysis. In addition to scientists who are cited frequently in the literature because of their contribution to cognitive research programmes, it also identifies discipline builders and institutionalizers – those administrators and meeting organizers whose scientific contributions may have been less important than their organizational efforts – people who are founders of disciplines rather than of cognitive research programmes.⁴³ 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.

Finally, this new prosopographical approach will be especially useful in the case of emerging new disciplines, or those undergoing rapid conceptual change (such as immunology). As late as the 1950s and 1960s, there were very few immunological departments and few clearly-defined immunological journals. Much of the newer work emerged from pathology, pediatric, medicine and surgical departments, and was published in a host of journals not immediately identifiable as immunological. In such instances, citation analysis and co-citation analysis of scientific literature may not provide particularly useful data for prosopographical analysis. But meetings do, particularly international meetings such as analyzed here. They were launched as active agents in the institutionalization of the disciplinary transition of immunology of the 1950s and 1960s, and more clearly represent the conceptual movement of the field, of its research programmes and of its changing leadership.

A few caveats should be entered in assessing the value of this approach. We have not proved that the master file of 4806 meeting participants is coextensive with the community of immunologists of the period. But according to our own experience, there is hardly an immunologist (of the Western world) who did not attend at least one of these meetings. However, in excluding from the study the meetings of national immunological societies (and particularly the annual meetings of the American Association of Immunologists) we assume that the master list may under-represent junior

scientists or those who flirted only transiently with immunology, and who attended only national or local meetings. Yet another shortcoming of the analysis of disciplinary leaders in terms of meeting attendance involves those whose importance may be understated because they left the field early or entered it late, or simply do not like to travel. Nevertheless, we believe that the $n=311$ file (attendees at five or more meetings) fairly represents that community of immunological leaders with a long-standing international orientation – the major immunologists of the 1950s and 1960s.

Cluster analysis of meetings in terms of overlapping participants reveals several important new dimensions. Not only does it define the cognitive movement of the field in terms of the attendance ‘votes’ of the disciplinary (and even subdisciplinary) élite, but it also serves to define the distance between subdisciplines and the timing of entry of a subdiscipline into the mainstream of the field. However, even here there is a minor procedural defect: when a given meeting is clustered together with certain other meetings, it is withdrawn from further comparison with all other meetings, thus concealing second-order relationships. This may be overcome by inspecting the similarity indices between each meeting and *all* others, in which case these additional relationships emerge.

We should also indicate some of the paths that future research using prosopographical data of meetings might follow. The most obvious possibility is to enlarge the database in different ways. The time window should be expanded, both backward and forward in the representation of frequent meeting participants, and to illuminate the structural changes in immunology throughout the century. Likewise, the selection of meetings might be expanded to include (a) national meetings; (b) significant unpublished meetings such as the series of Antibody, Complement, and Delayed Hypersensitivity Workshops; and (c) immunological sessions within other meetings, such as international congresses of microbiology, hygiene, medicine and pathology.

The database could also be expanded to include more extensive biographical information. Since lists of participants often contain information about departmental affiliation and even 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. In addition, the quality of participation

by individuals may tell much about their standing in the community; obviously, there are recognized differences between invited keynote and minisymposium speakers and self-volunteered presenters or passive attendees. Similarly, there are hierarchical differences between internationally recognized invitees to small elite meetings and the auditors of larger ones.

Another direction in which the database might be expanded meaningfully would be to include information about keywords in the titles of meetings and in the papers presented.⁴⁴ This would permit a more precise tracking of the cognitive developments within the discipline, and a more exact timing of the joining of new subdisciplines (for example, allergy or transplantation) into the mainstream.

Finally, in a larger context, meetings deserve the attention of scholars of social studies of science in a number of ways we have not been able to deal with here. To take one single example: we lack empirical analyses of the negotiation of conference topics, based on ethnographic observations or on retrospective interviews with those who organized these meetings. A fuller understanding of the reasons for the distribution of participants among scientific meetings calls for future sociological and ethnographic analysis of this neglected topic in social studies of science.

• APPENDIX

88 Selected Immunological Meetings 1951–72

Meeting identification notations refer to the main text and to Figure 2. The suffix numbers identify (the last two digits of) the year. The prefix letters refer to the following meeting series (full literature references are given in the notes):

Tran: New York Academy of Sciences transplantation meetings⁴⁵ and its successor, the International Congresses of the Transplantation Society⁴⁶

Imp: Immunopathology Symposia⁴⁷

Ciba: Ciba Foundation series⁴⁸

Prag: Prague series⁴⁹

BrLo: Brook Lodge series⁵⁰

Germ: Germinal Center series⁵¹

Buff: Buffalo Convocations⁵²

Hist: Histocompatibility Workshops⁵³

Sani: Sanibel Island series⁵⁴

Leuko: Leukocyte Culture series⁵⁵

Alle: Collegium Internationale Allergologicum series⁵⁶

Cold: Cold Spring Harbor series⁵⁷

IntC: International Congresses of Immunology⁵⁸

sing: singular meetings outside series⁵⁹

1951:

sing1–51: The nature and significance of the antibody response (New York, NY).

1953:

Ciba1–53: Preservation and transplantation of normal tissues (London, England).

1954:

Tran1–54: The relation of immunology to tissue homotransplantation (New York, NY).

Alle1–54: Aspects of allergy research (London, England).

1955:

Alle2–55: Migraine and vascular allergy (Basel, Switzerland).

1956:

Tran2–56: Second tissue homotransplantation conference (New York, NY).

sing2–56: Immunology and development (Bar Harbor, ME).

1957:

Alle3–57: Third symposium; Collegium Internationale Allergologicum (London, England).

sing3–57: Allergic encephalomyelitis (Bethesda, MD).

1958:

sing4–58: Cellular and humoral aspects of hypersensitivity states (New York, NY).

sing5–58: Mechanisms of hypersensitivity (Detroit, MI).

Tran3–58: Third tissue homotransplantation conference (New York, NY).

Immp1–58: Immunopathology – Immunopathologie (Seelisberg, Germany).

1959:

Alle4–59: Fourth symposium; Collegium Internationale Allergologicum (Rome, Italy).

Prag2–59: Mechanisms of antibody formation (Prague, Czechoslovakia).

Ciba2–59: Cellular aspects of immunity (Royauumont, France).

1960:

Tran4–60: Fourth tissue homotransplantation conference (New York, NY).

sing6–60: Immunochemical approaches to problems in microbiology (New Brunswick, NJ).

1961:

sing7–61: International symposium on tissue transplantation (Santiago, Chile).

Prag3–61: Mechanisms of immunological tolerance (Prague, Czechoslovakia).

Immp2–61: Mechanism of cell and tissue damage produced by immune reactions (Brook Lodge, MI).

1962:

Alle5–62: Fifth symposium; Collegium Internationale Allergologicum (Freiburg, Germany).

Tran5–62: Fifth tissue homotransplantation conference (New York, NY).

sing8–62: The thymus in immunobiology (Minneapolis, MN).

1963:

sing9–63: Cell bound antibodies (Washington, DC).

Ciba4–63: The immunologically competent cell (London, England).

Immp3–63: Immunopathology (La Jolla, CA).

1964:

Prag4–64: Molecular and cellular basis of antibody formation (Prague, Czechoslovakia).

sing10–64: The thymus (Philadelphia, PA).

sing11–64: Autoimmunity: experimental and clinical aspects (New York, NY).

Tran6–64: Sixth international transplantation conference (New York, NY).

Alle6–64: Sixth symposium; Collegium Internationale Allergologicum (London, England).

Hist1–64: Histocompatibility testing – 1964 (Durham, NC).

1965:

Sani1–65: Phylogeny of immunity (Sanibel Island, FL).

Ciba5–65: Complement (London, England).

Ciba6–65: The thymus; experimental and clinical studies (London, England).

Immp4–65: Immunopathology; Fourth international symposium (Monte Carlo).

Leuko1–65: Leukocyte culture workshop (Washington, DC).

1966:

Tran7–66: Seventh international transplantation conference (New York, NY).

Germ1–66: Germinal centres in immune responses (Bern, Switzerland).

Sani2–66: Ontogeny of immunity (Sanibel Island, FL).

sing12–66: Regulation of the antibody response (Toronto, Ontario).

1967:

sing13–67: Gamma globulins: structure and control of biosynthesis (Stockholm, Sweden).

sing14–67: Nucleic acids in immunology (New Brunswick, NJ).

sing15–67: Differentiation and immunology (Gatlinburg, TN).

Leuko3–67: Third leukocyte culture conference (Iowa City, IA).

Sani3–67: Immunologic deficiency diseases of man (Sanibel Island, FL).

Hist3–67: Histocompatibility testing – 1967 (Turin, Italy).

Immp5–67: Immunopathology; Fifth international symposium (Punta Ala, Israel).

Tran8–67: Advance in transplantation (Paris, France).

Cold1–67: Cold Spring Harbor symposium on antibodies (Cold Spring Harbor, NY).

1968:

Buff1–68: First international convocation on immunology (Buffalo, NY).

Germ2–68: Lymphatic tissue and germinal centres in immune responses (Padua, Italy).

Tran9–68: The second international congress of the Transplantation Society (New York, NY).

Alle7–68: Seventh symposium; Collegium Internationale Allergologicum (Tel Aviv, Israel).

BrLo1–68: Immunological tolerance (Brook Lodge, MI).

sing16–68: The immune response and its suppression (Davos, Switzerland).

sing17–68: Current problems in immunology (Grosse Ledder, Germany).

sing18–68: Organ transplantation today (Amsterdam, The Netherlands).

1969:

sing19–69: Human anti-human gammaglobulins: their specificity and function (Lund, Sweden).

Buff2–69: Cellular interactions in the immune response (Buffalo, NY).

BrLo2–69: Mediators of cellular immunity (Brook Lodge, MI).

Sani4–69: The secretory immunologic system (Sanibel Island, FL).

Prag5–69: Developmental aspects of antibody formation and structure (Prague, Czechoslovakia).

Leuko4–69: Fourth annual leukocyte culture conference (Hanover, NH).

1970:

Leuko5–70: Fifth annual leukocyte culture conference (Ottawa, Ontario).

Immp6–70: Immunopathology; sixth international symposium (Grindelwald, Germany).

Prag6–70: Immunogenetics of the H-2 system (Prague, Czechoslovakia).

Hist4–70: Histocompatibility testing – 1970 (Los Angeles, CA).

Tran10–70: Third international congress of the Transplantation Society (The Hague, The Netherlands).

Alle8–70: Eighth symposium; Collegium Internationale Allergologicum (Montreux, France).

sing20–70: Cell interactions and receptor antibodies in immune responses (Helsinki, Finland).

sing21–70: Role of lymphocytes and macrophages in the immune response (Munich, Germany).

Germ3–70: Morphologic and functional aspects of immunity (Uppsala, Sweden).

BrLo3–70: Immune surveillance (Brook Lodge, MI).

1971:

IntC1–71: First international congress in immunology (Progress in immunology) (Washington, DC).

BrLo4–71: Immunologic intervention (Brook Lodge, MI).

Ciba7–71: Ontogeny of acquired immunity (London, England).

Leuko6–71: Sixth leukocyte culture conference, (San Juan Islands, WA).

1972:

Leuko7-72: Seventh leukocyte culture conference (Quebec, Canada).

Ciba8-72: Corneal graft failure (London, England).

BrLo5-72: Genetic control of immune responsiveness (Brook Lodge, MI).

Germ4-72: Microenvironmental aspects of immunity (Dubrovnik, Yugoslavia).

Buff3-72: Specific receptors of antibodies, antigens, and cells (Buffalo, NY).

Hist5-72: Histocompatibility testing – 1972 (Evian, Switzerland).

Sani5-72: The biological role of the immunoglobulin E system (Vero Beach, FL).

Alle9-72: Ninth symposium; Collegium Internationale Allergologicum (London, England).

Tran11-72: Fourth international congress of the Transplantation Society (San Francisco, CA).

• NOTES

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1. *Les Congrès internationaux de 1681 à 1899: liste complète* (Brussels: Union des Associations Internationales, 1960), quoted from B. Schroeder-Gudehus, Chapter 13, 'Science, Technology and Foreign Policy', in I. Spiegel-Rösing and D. de Solla Price (eds), *Science, Technology and Society* (London: Sage, 1977), 473–506.

2. R.H. Orr, E.B. Coyl and A.A. Leeds, 'Trends in Oral Communication Among Biomedical Scientists: Meetings and Travel', *Federation Proceedings*, Vol. 23 (1964), 1146–54 (data from Figure 1).

3. *Ibid.* The Federation is comprised of seven member societies dealing with physiology, biochemistry and molecular biology, pharmacology and experimental therapeutics, pathology, nutrition, immunology and cell biology.

4. This view of meetings is adopted by analogy with Timothy Lenoir's discussion of scientific disciplines: see T. Lenoir, 'The Discipline of Nature and the Nature of Disciplines', in E. Messer-Davidow, D. Silvan and D. Shumway (eds),

Knowledges: Historical and Critical Studies in Disciplinarity (Charlottesville, VA: University of Virginia Press, in press).

5. See, for example, Anon., 'Communication Problems in Biochemical Research: Report of a Study', *Federation Proceedings*, Vol. 23 (1964), 1117–32, at 1121; P.K. Woolf, 'The Second Messenger: Informal Communication in Cyclic AMP Research', *Minerva*, Vol. 13 (1975), 349–73; W.D. Garvey, N. Lin, C.E. Nelson and K. Tomita, 'Research Studies in Patterns of Scientific Communication: II, The Role of the National Meeting in Scientific and Technical Communication', in W.D. Garvey (ed.), *Communication: The Essence of Science* (Oxford: Pergamon Press, 1979), 184–201 (Appendix B); and W.S. Lyon, 'Scientometrics with Some Emphasis on Communication at Scientific Meetings and Through the "Invisible College"', *Journal of Chemical Information and Computer Sciences*, Vol. 26 (1986), 47–52.

6. B. Martens and T. Saretzki, 'Conferences and Courses on Biotechnology; Describing Scientific Communication by Exploratory Methods', *Scientometrics*, Vol. 27 (1993), 237–60.

7. D. Crane, *Invisible Colleges: Diffusion of Knowledge in Scientific Communities* (Chicago, IL: University of Chicago Press, 1972). Chubin's bibliography of the literature on invisible colleges has no references to studies of meetings, either: see D. Chubin, *Sociology of Sciences: An Annotated Bibliography on Invisible Colleges* (New York: Garland, 1983). Neither R.K. Merton, *The Sociology of Science: Theoretical and Empirical Investigations* (Chicago, IL: University of Chicago Press, 1973), nor one of the classic texts on the topic of the emergence of scientific disciplines that otherwise focuses on the social processes in a scientific community associated with scientific development – G. Lemaine, R. Macleod, M. Mulkay and P. Weingart (eds), *Perspectives on the Emergence of Scientific Disciplines* (The Hague: Mouton, 1976) – pay any notice to the role of scientific meetings. Warren Hagstrom spends a few pages in *The Scientific Community* on a discussion of the function of meetings for informal scientific recognition and supports the view, also frequently made by scientists, that the major reason scientists go to meetings is to meet colleagues face to face for informal recognition: see W.O. Hagstrom, *The Scientific Community* (New York: Basic Books, 1965), 29–33. The 1968 edition of the *International Encyclopedia of the Social Sciences* mentions meetings as a minor adjunct to published literature: 'journals, books, and even meetings' (our emphasis), are taken as examples of structured channels of communication, and a few investigations that point to an increase in the number of meetings and the participation in meetings are cited: see N. Kaplan and N.W. Storer, 'Scientific Communication', *International Encyclopedia of the Social Sciences*, Vol. 14 (1968), 112–17.

8. Although F.W. Wolek and B.C. Griffith, in a Discussion Paper entitled 'Policy and Informal Communications in Applied Science and Technology', *Science Studies*, Vol. 4 (1974), 411–20, referred to the topic.

9. A paradigmatic study of the use of meetings as a 'mirror' of scientific development is A. Bauer, *Die Krankheitslehre auf dem Weg zur Naturwissenschaftlichen Morphologie: Pathologie auf den Versammlungen Deutscher Naturforscher und Ärzte von 1822–1872*, Schriftenreihe zur Geschichte der Versammlungen Deutscher Naturforscher und Ärzte. Bd. 4 (Stuttgart: Wissenschaftliche Verlagsgesellschaft, 1989). Other examples include Mehra's study of the Solvay conferences in physics as a record of the development of twentieth-century theoretical physics –

J. Mehra, *The Solvay Conferences on Physics: Aspects of the Development of Physics Since 1911* (Dordrecht: Reidel, 1975) – and Howard-Jones's study of the international sanitary conferences 1851–1938 as a contribution to the history of public health: N. Howard-Jones, *The Scientific Background of the International Sanitary Conferences 1851–1938* (Geneva: World Health Organization, 1975).

10. But the use of meeting material varies. In his *Science and Medicine in France: The Emergence of Experimental Physiology, 1790–1855* (Cambridge, MA: Harvard University Press, 1984), John Lesch mentions meetings in passing only, whereas in 'The Paris Academy of Medicine and Experimental Sciences, 1820–1948', in W. Coleman and F.L. Holmes (eds), *The Investigative Enterprise: Experimental Physiology in Nineteenth-Century Medicine* (Berkeley, CA: University of California Press, 1988), 100–38, he discusses the Academy's Memoirs and *procès-verbaux* in some detail. Other studies of scientific societies do not single out meetings for analysis: see, for example, T.L. Haskell, *The Emergence of Professional Social Science: The American Social Science Association and the Nineteenth-Century Crisis of Authority* (Urbana, IL: University of Illinois Press, 1977).

11. For example, Means uses the *Transactions* of the Association of the American Physicians meetings to write a 'life and letters of the AAP': J.H. Means, *The Association of American Physicians: Its First Seventy-Five Years* (New York: McGraw Hill, 1961). The centennial history of the American Physiological Society devotes a chapter to the society's biannual meetings: M.J. Jackson and J.F. Saunders, 'Spring and Fall Scientific Meetings', in J.R. Brobeck, O.E. Reynolds and T.A. Appel (eds), *History of the American Physiological Society: the First Century, 1887–1987* (Bethesda, MD: American Physiological Society, 1987), 315–32. Most histories of scientific societies are based on minutes and proceedings of meetings, but as far as we can tell these studies have not involved prosopographical analysis.

12. Bruce Fye lists attendance at the regular meetings of the American physiological society, 1887–99, in absolute numbers and percentage of members only, without any attempt at prosopographical analysis: W.B. Fye, *The Development of American Physiology: Scientific Medicine in the Nineteenth Century* (Baltimore, MD: The Johns Hopkins University Press, 1987), in Appendix 3. Michael Jackson and Joseph Saunders (op. cit. note 11) listed attendance numbers (and attendance in percentage of total membership), number and distribution (by specialty) of volunteered papers 1962–85, and distribution by mode of delivery 1974–85, in a chapter on meetings in the history of the American Physiological Society. By surveying the topics, sources and sites of abstracts from annual meetings of three clinical research organizations, Feinstein and his colleagues have demonstrated a trend away from classical clinical research in the years 1953–67, concomitant with an increase of 'basic' research topics: A.R. Feinstein, N. Koss and J.H.M. Austin, 'The Changing Emphasis on Clinical Research: I. Topics Under Investigation: An Analysis of the Submitted Abstracts and Selected Programs at the Annual "Atlantic City Meetings" During 1953–1965', *Annals of Internal Medicine*, Vol. 66 (1967), 396–419; Feinstein and Koss, '... II: Sites and Sources of the Investigations', *ibid.*, 420–34; Feinstein and Koss, '... III: Follow-Up Report for the Years 1965–1969', *ibid.*, Vol. 125 (1970), 885–91.

13. Exceptions include, for example, F.P. Woodford, *The Ciba Foundation: An Analytic History 1949–1974* (Amsterdam: Elsevier, 1974), and Elizabeth M.

Paterson, *History of the National Conference of Tuberculosis Workers 1909–1955* (New York: National Tuberculosis Association, 1956). (The latter is rather an example of the role of meetings in the formation of a profession.) In their study of the emergence of radio astronomy, David Edge and Michael Mulkey listed the number of meeting participants and analyzed submitted papers by contents: D. Edge and M. Mulkey, *Astronomy Transformed: The Emergence of Radio Astronomy in Britain* (New York: John Wiley, 1976), 48, 50–51. Pnina Abir-Am has analyzed in detail the meetings of the 'Biotheoretical Gathering' in the 1930s: P. Abir-Am, 'The Biotheoretical Gathering, Transdisciplinary Authority and the Incipient Legitimation of Molecular Biology in the 1930s: New Perspective on the Historical Sociology of Science', *History of Science*, Vol. 25 (1987), 1–70.

14. For example, S. Shapin, 'Phrenological Knowledge and the Social Structure of Early Nineteenth-Century Edinburgh', *Annals of Science*, Vol. 32 (1975), 219–43.

15. See the journal *Scientometrics*.

16. E. Kranakis and L. Leydesdorff, 'Teletraffic Conferences: Studying a Field of Engineering Science', *Scientometrics*, Vol. 15 (1989), 563–91.

17. Between 1880 and about 1910, immunological research dealt primarily with the medical aspects of infectious diseases. From 1910 to the 1950s, it was predominantly chemically oriented. The history of immunology is more fully described in: A.M. Moulin, *Le dernier langage de la médecine: Histoire de l'immunologie de Pasteur au Sida* (Paris: Presses Universitaires, 1991), A.M. Silverstein, *A History of Immunology* (New York: Academic Press, 1989), A.I. Tauber and L. Chernyak, *Metchnikoff and the Origins of Immunology* (New York: Oxford University Press, 1991), and G. Corbellini, *L'evoluzione del pensiero immunologico* (Torino: Bollati Boringhieri, 1990).

18. During the late 1950s and early 1960s, there occurred a major transition to more biomedical concerns, which was described as a 'paradigm shift': A.M. Silverstein, 'The Dynamics of Conceptual Change in Twentieth-Century Immunology', *Cellular Immunology*, Vol. 132 (1991), 515–31.

19. The American society was founded in 1913 and the British society in 1959. In the late 1960s followed Australia, Canada, France, West Germany, Israel, The Netherlands, Poland, Switzerland, Scandinavia and Yugoslavia; in the 1970s societies were founded in Argentina, Austria, Belgium, Brazil, Chile, East Germany, Greece, Hungary, India, Italy, Japan, Nigeria, Portugal, Romania, Spain and Turkey. The creation of these societies and the organization of national and international meetings with an explicit immunological agenda is itself a fundamental aspect of the process of discipline formation which we shall not explore further here.

20. Of 58 questionnaires sent out, 40 responses were returned.

21. The problem of the social construction of international reputation is not taken up in this preliminary report.

22. For example, the programme of the VIII International Congress of Immunology, (Budapest, 1992), listed 25 symposia, 7 special lectures and 134 workshops over a period of five days. In addition, numerous satellite symposia on specific subdisciplinary topics were held all over Europe in conjunction with the Congress.

23. Aims are notoriously difficult to analyze and reconstruct. We restrict ourselves here to the explicit aims of the organizers.

24. However, we have incorporated one unpublished meeting – namely, the

1965 Leukocyte Culture Workshop – which belongs to an otherwise published series, and where we have been able to locate the programme and list of participants.

25. For example, the Antibody Workshops, initiated in the late 1950s (for a historical sketch, see R.R. Porter, 'Antibody Structure and the Antibody Workshops 1958–1965', *Perspectives in Biology and Medicine*, Vol. 29 [1986], 161–65); the Delayed Hypersensitivity Workshops, started in the early 1960s; and the Complement Workshops, which began to meet in the late 1960s. The Allergy Round Tables have an even longer history, recounted by L. Tuft, *NER Allergy Proceedings*, Vol. 6 (1985), 279–84. The Gordon Conferences devoted to immunology fulfilled both research and educational functions, but have been excluded from this study for similar reasons.

26. For example, meetings such as *Forensic Immunology, Medicine, Pathology, and Toxicology* (London, 1963) and *Immunity in Viral and Rickettsial Diseases* (Israel, 1972) were excluded. Other examples are the US Public Health Service Immunization Conferences devoted to governmental immunization programmes, meetings on 'Immunology of the Liver', 'Immunoassay of Hormones', and the like, in which immunological problems did not figure prominently, and meetings on 'Immunity in Viral and Rickettsial Diseases', devoted primarily to the pathogens themselves. Furthermore, we have restricted our analysis of allergology meetings to the series of Collegium Internationale Allergologicum; we do not expect the seven congresses of the International Association of Allergology (1951–70) to change the result of the analysis significantly.

27. Usually proceedings list 'contributors' – that is, 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 over-representation 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.

28. Lenoir, op. cit. note 4. Although we do not share Lenoir's argument against a biographical or prosopographical understanding of scientific disciplines, we find his distinction between founders of cognitive research programmes and founders of disciplines ('discipline builders, entrepreneurs, and scientific gatekeepers') useful for our present purpose.

29. A statistically more satisfying test of the correlation is complicated by the fact that the less frequent participants with common names are difficult to identify unambiguously in the *Science Citation Index*. We will treat this problem in a forthcoming study.

30. One notable example of this category is Niels K. Jerne, who is generally considered to be one of the most prominent immunologists in the world in the 1960s and 1970s, and who was awarded the Nobel Prize in Medicine 1984. Yet with seven meetings attended, Jerne is not even among the 100 most frequent meeting-goers.

31. For a general introduction, see, for example, A.D. Gordon, *Classification* (London: Chapman & Hall, 1981), particularly Chapters 2 and 3. A more advanced introduction is: Leonard Kaufman and Peter J. Rousseeuw, *Finding Groups in Data: An Introduction to Cluster Analysis* (New York: John Wiley, 1990).

32. H.G. Small, 'A Co-citation Model of a Scientific Specialty: A Longitudinal Study of Collagen Research', *Social Studies of Science*, Vol. 7 (1977), 139–66.

33. Cf. Gordon, *op. cit.* note 31.

34. SAS program licensed to Stanford University.

35. SAS System's Centroid and Median Cluster Analysis gave no or almost no resolution. Average Linkage, Single Linkage and Complete Linkage Analysis all gave good resolution, but only Average Linkage appeared without 'ties' – that is, points where the computer program chooses arbitrarily between two higher units with identical similarity measures. However, the results obtained with Single Linkage and Complete Linkage Analysis methods were not much different from results obtained with Average Linkage Analysis.

36. The progressive reduction in the number of participants results in an increasing reduction in the number of meetings in the matrix; for example, only 79 meetings were attended by participants belonging to the small disciplinary élite that attend 15 or more meetings.

37. 'Meeting choice' also covers the behaviour of choosing to accept an invitation.

38. The International Union of Immunological Societies was formed at a meeting in 1969 among representatives from eleven national immunological societies, to coordinate all international activities and to sponsor the International Congresses of Immunology (minutes from meeting of the IUIS, 5 May 1969); for a historical sketch, see B. Cinader, 'The Origins and Early Years of IUIS', *Immunology Today*, Vol. 13 (1992), 323–26.

39. For a history of the Ciba Foundation meetings and their stated purpose, see Woodford, *op. cit.* note 13.

40. Silverstein, *op. cit.* notes 17 and 18.

41. Sheldon Cohen, personal communication to Arthur M. Silverstein, November 1991.

42. Much of the early history of histocompatibility antigens and of the workshop series may be found in P.I. Teresaki (ed.), *History of HLA: 10 Recollections* (Los Angeles, CA: University of California Press, 1990), and in D.B. Amos, 'Fundamental Antigens of HLA', *Human Immunology*, Vol. 30 (1991), 236–46.

43. Lenoir, *op. cit.* note 4.

44. Cf. Kranakis & Leydesdorff, *op. cit.* note 16.

45. *Annals of the New York Academy of Sciences*, Vol. 59 (1955), 277–466; Vol. 64 (1957), 735–1073; Vol. 73 (1958), 539–868; Vol. 87 (1960), 1–607; Vol. 99 (1962), 335–942; Vol. 120 (1964), 1–806; Vol. 129 (1966), 1–884.

46. J. Dausset, J. Hamburger and G. Mathé (eds), *Advance in Transplantation: Proceedings of the First International Congress of the Transplantation Society* (Baltimore, MD: Williams & Wilkins, 1968); 'Proceedings of the Second International Congress of the Transplantation Society New York, 1968', *Transplantation Proceedings*, Vol. 1 (1969), 1–681; 'Proceedings of the Third International Congress of the Transplantation Society, The Hague, 1970', *ibid.*, Vol. 3 (1971), 1–978; 'Proceedings of the Fourth International Congress of the Transplantation Society, San Francisco, 1972', *ibid.*, Vol. 5 (1973), 1–1016.

47. P. Grabar and P.A. Miescher (eds), *Immunopathology – Immunopathologie: 1st International Symposium on Immunopathology* (Basel: Benno Schwabe, 1959); Grabar and Miescher (eds), *Mechanism of Cell and Tissue Damage Produced by Immune Reactions: 2nd International Symposium on Immunopathology* (New

York: Grune & Stratton, 1962); Grabar and Miescher (eds), *Immunopathology: 3rd International Symposium* (Basel: Benno Schwabe, 1963); Grabar (ed.), *Immunopathology: 4th International Symposium* (New York: Grune & Stratton, 1965); Miescher and Grabar (eds), *Immunopathology: 5th International Symposium* (New York: Grune & Stratton, 1967); Miescher (ed.), *Immunopathology: 6th International Symposium* (New York: Grune & Stratton, 1971).

48. G.E.W. Wolstenholme and M.P. Cameron (eds), *Preservation and Transplantation of Normal Tissues* (Boston, MA: Little, Brown, 1954); Wolstenholme and M. O'Connor (eds), *Cellular Aspects of Immunity* (Boston, MA: Little, Brown, 1960); Wolstenholme and J. Knight (eds), *The Immunologically Competent Cell* (Boston, MA: Little, Brown, 1963); Wolstenholme and Knight (eds), *Complement* (Boston, MA: Little, Brown, 1965); Wolstenholme and R. Porter (eds), *The Thymus: Experimental and Clinical Studies* (Boston, MA: Little, Brown, 1966); Porter and Knight (eds), *Ontogeny of Acquired Immunity* (New York: Elsevier, 1972); Porter and Knight (eds), *Corneal Graft Failure* (New York: Elsevier, 1973).

49. M. Holub and L. Jarosková (eds), *Mechanisms of Antibody Formation* (Prague: Czechoslovak Academy of Sciences, 1960); M. Hasek, A. Lengerová and M. Vojtisková (eds), *Mechanisms of Immunological Tolerance* (Prague: Czechoslovak Academy of Sciences, 1962); J. Sterzl (ed.), *Molecular and Cellular Basis of Antibody Formation* (Prague: Czechoslovak Academy of Sciences, 1965); Sterzl and I. Ríha (eds), *Developmental Aspects of Antibody Formation and Structure*, 2 Vols (Prague: Academia, 1970); Lengerová and Vojtisková (eds), *Immunogenetics of the H-2 System* (Basel: Karger, 1971).

50. M. Landy and W. Braun (eds), *Immunological Tolerance* (New York: Academic Press, 1969); H.S. Lawrence and Landy (eds), *Mediators of Cellular Immunity* (New York: Academic Press, 1969); R.T. Smith and Landy (eds), *Immune Surveillance* (New York: Academic Press, 1970); J.W. Uhr and Landy (eds), *Immunologic Intervention* (New York: Academic Press, 1971); Landy and H. McDevitt (eds), *Genetic Control of Immune Responsiveness* (New York: Academic Press, 1972).

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53. D.B. Amos (ed.), *Histocompatibility Testing, 1964* (Washington, DC: National Academy of Science, Publication No. 1229, 1965); R. Ceppellini (ed.), *Histocompatibility Testing, 1967* (Baltimore, MD: Williams & Wilkins; Copenhagen: Munksgaard, 1968); P. Teresaki (ed.), *Histocompatibility Testing, 1970* (Baltimore, MD: Williams & Wilkins; Copenhagen: Munksgaard, 1971); J.

Dausset (ed.), *Histocompatibility Testing, 1972* (Baltimore, MD: Williams & Wilkins; Copenhagen: Munksgaard, 1973).

54. R.T. Smith, P.A. Miescher and R.A. Good (eds), *Phylogeny of Immunity* (Gainesville, FL: University of Florida Press, 1966); Smith, Good and Miescher (eds), *Ontogeny of Immunity* (Jacksonville, FL: University of Florida Press, 1967); D. Bergsma (ed.), *Immunologic Deficiency Diseases of Man* (New York: The National Foundation, 1967); D.H. Dayton, P.A. Small, R.M. Chanock, H.E. Kaufman and T.B. Tomasi (eds), *The Secretory Immunologic System* (Washington, DC: US Government Printing Office, 1970); K. Ishizaka and Dayton (eds), *The Biological Role of the Immunoglobulin E System* (Washington, DC: US Government Printing Office, 1973).

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56. *International Archive for Allergy and Applied Immunology*, Vol. 6 (1955), 193–395; Vol. 7 (1955), 193–444; Vol. 11 (1957), 1–341; Vol. 18 (1961), 1–236; Vol. 22 (1963), 69–421; Vol. 28 (1964), 1–140; Vol. 36 (1969), 1–218; Vol. 41 (1970), 1–236; Vol. 45 (1973), 1–329.

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