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University Social Structure and Social Networks among Scientists¹

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Findings are presented that describe the pattern of research communication among faculty in the six physical science departments of an elite American university. The findings provide a basis for modifying and extending Peter Blau's analysis of the relationship between university social structure and the pattern of communication among university faculty. Blau regards the formation of integrative multidisciplinary social networks within university communities as highly problematic; he suggests that academic departments are the primary site of integrative social networks within universities. My findings suggest that academic departments are not appropriate units for describing the pattern of research communication among university faculty, at least in the physical sciences, and that university social structure can foster an integrative social network which is multidisciplinary in composition. Proposals are introduced that relate facets of university social structure to the formation of integrative multidisciplinary social networks. A perspective on the role of universities in fostering the coherence of the scientific elite is outlined.

Nearly all investigators of social networks among scientists have looked at those connections that are based on the scientists' activities in a single subfield, specialty, or discipline (Breiger 1976; Crane 1969, 1972; Crawford 1970; Gaston 1973; Griffith, Jahn, and Miller 1971; Griffith and Miller 1970; Griffith and Mullins 1972; Mullins 1972; Mulkey, Gilbert, and Woolgar 1975; Price and Beaver 1966). Consequently, very little is known about the morphology of those social networks that involve scientists from different disciplines. There are some data which confirm the impression that the boundaries of research areas are very much open (Crane 1972; Crawford 1970). Metaphors such as "overlapping neighborhoods" (Polanyi 1962), "honeycomb structure" (Crane 1972), and "fish scales" (Campbell 1969) have been used to describe the general pattern of interdisciplinary communication that is believed to exist. But thus far only Nicholas Mullins (1966, 1968) has examined a social network composed of scientists at work

¹This paper is based on the author's dissertation work, which was conducted at the University of Chicago. I am deeply indebted to Charles Bidwell, my principal adviser, and to Robert Dreeben, Mark Joseph, and the anonymous referees who supplied valuable comments.

in different disciplines (primarily in the biological sciences). Mullins's study of this multidisciplinary population suggests that it is joined by a structurally diffuse and loosely meshed social network.

Social network morphology may have important implications. It is plausible that scientific information of various kinds is transmitted more easily in networks where pairs of persons are on the average connected by a host of fairly short communication paths than in networks where pairs of persons tend to be connected by only a few paths of short length; accordingly, different social network patterns may be differently conducive to the diffusion of scientific knowledge and to the visibility of scientific role performance (see Cole and Cole 1968; Coleman, Katz, and Menzel 1966; Granovetter 1974; Kerckhoff, Back, and Miller 1965; Merton 1968, pp. 390–407). Different social network patterns may also be differently conducive to the crystallization and reinforcement of moral consensus among scientists and to the capacity of scientists to rouse themselves for collective action (cf. Festinger, Schachter, and Back 1950; Laumann and Pappi 1976; Mitchell 1969; Riley and Cohn 1958). Social networks have repeatedly been pointed to as significant phenomena; but at present this idea, that the morphology of social networks has important social correlates, is a gleam in the eyes of network theorists.

Although our knowledge of the relationship between network morphology and various social phenomena is rudimentary, network analysts tend to agree that larger numerical values on such morphological parameters as network density, compactness, and mesh are associated with socially integrative effects (Barnes 1972; Mitchell 1969). Elizabeth Bott perhaps most explicitly asserts this fundamental preconception of much network analysis:

When many of the people a person knows interact with one another, that is when the person's network is close-knit, the members of his network tend to reach consensus of norms and they exert consistent informal pressure on one another to conform to the norms, to keep in touch with one another, and, if need be, to help one another. . . . But when most of the people a person knows do not interact with one another, that is when his network is loose-knit, more variation on norms is likely to develop in the network and social control and mutual assistance will be more fragmented and less consistent. [Bott (1957) 1971, p. 60]

Bott's perspective reflects a tradition in social analysis that has its roots in early sociometric studies (e.g., Moreno 1934) and in later graph theoretic formulations (e.g., Harary, Norman, and Cartwright 1965), a tradition which is now being vigorously carried forward in the work of certain sociologists (e.g., Granovetter 1973, 1976; Laumann 1973; Laumann and Pappi 1976) and social anthropologists (see the reviews of Barnes 1972; Mitchell 1969; Whitten and Wolfe 1973). My present work is informed by this tradition, which has pointed to the significance of social networks and their

variations in morphology. In light of this tradition, it appears problematic whether Mullins's data indicate the kind of social network morphology among scientists which can be an effective basis for the diffusion of scientific information across disciplinary lines or which Polanyi (1962) suggests might be the "seat" of a uniform scientific opinion.

No one has previously examined a social network composed of scientists at work in different disciplines within a single university. There are, of course, research-oriented universities that support concentrations of active scientists at work in a variety of disciplines. My present work was motivated by the idea that these research-oriented universities are likely sites for finding more structurally cohesive multidisciplinary networks than Mullins's data suggest exist in science.

Peter Blau (1973), who recently proposed that the academic departments of universities can be sites of cohesive social networks, is skeptical of the idea that universities can be loci of cohesive multidisciplinary social networks:

The differentiation of academic institutions into specialized departments, far from integrating them by making them highly interdependent, weakens their integration by creating obstacles to communication among them. [P. 265]

In other organizations, the differentiation of the common task into interdependent functions creates simultaneously a basis for integration, because the interdependence of parts requires them to cohere and helps integrate them. But the academic specialties in a university are not directly interdependent. The members of each can pursue their research and teaching independently of the work of others, and the high degree of specialization makes communication between different fields difficult. The fact—assuming it is a fact—that integration is more problematical in universities is ironical, since the very term "university" implies an integrated whole. . . . [P. 215]

In this paper I present some findings on the pattern of research communication among 128 faculty in the six physical science departments of an elite American university. I propose an explanation of how university social structure may act to foster the structural cohesiveness of multidisciplinary research networks. Finally, I speculate on some of the implications of my findings for the cohesiveness of the scientific elite.²

² The study deals with relationships in which, according to faculty reports, there is an ongoing substantive discussion of scientific ideas. Beyond these faculty reports, there are grounds for confidence that a social network is being scrutinized which is as professionally meaningful as those based exclusively on relationships among members of the same specialty or discipline. Pilot interviews, conducted with a small number of the faculty on the subject of the initiation of formal and informal research collaborations, first suggested that this university's faculty might draw extensively on the professional resources available not only in their own departments but also in the other departments of the university. Subsequently, it was found that at least 51% of the 128 faculty had published a paper

METHODS

The data of the present study were gathered from the population of assistant, associate, and full professors who had appointments in at least one of the physical science departments of a single university: astronomy, chemistry, geosciences, physics, mathematics, and statistics. These faculty were sent a questionnaire which listed the names of all other faculty in this population and requested the recipient to indicate those on the list with whom he had at least three conversations about *research problems* during the academic year. The possible number of survey respondents was 133; 71 faculty responded (53%). Analysis revealed that of the 133 faculty, 128 were linked in a single network of research communication, that is, a network in which each of the 128 faculty members was joined, directly or indirectly, to each of the other faculty members by one or more communication paths. The study deals with this network of 128 faculty.³

The network of physical scientists will be characterized as a whole, in terms of its density, compactness, and mesh. This network will be compared with another network of comparable size that consisted of scientists at work in a single specialty. This latter network I derived from Crawford's (1970) data on the pattern of research communication among scientists engaged in psychophysiological studies of sleep.⁴

with a fellow faculty member and that at least 41% were involved in a formal collaboration at the time of the survey. (These data are based on an item in the survey which requested faculty to indicate those faculty members with whom they had published a paper and/or with whom they were currently engaged in a research collaboration.) The distribution along departmental lines of these instances of (past and current) formal collaboration is isomorphic with the distribution of informal research relationships: 39% of the informal relationships in the network are interdepartmental, and 35% of the formal collaborations occurred among these interdepartmental relationships. These faculty are actively engaged in research programs: during 1973–75, at least 84% of the 128 faculty members published one or more research papers, and of these at least 63% published three or more papers. It is also noteworthy that 21 of these physical scientists are members of the National Academy of Sciences. I believe, in sum, that an inquiry into the presence of a structurally cohesive social network among the membership of this kind of multidisciplinary population may be a worthwhile endeavor. Some possible implications of such social networks are alluded to in the paper. But it must be clearly recognized that it is not the design of this study actually to demonstrate the nature of outcomes that either periodically or constantly flow from multidisciplinary research networks possessing certain morphologies. The study's primary focus is on the extent and manner in which university social structure may foster the production of a cohesive multidisciplinary research network.

³ A network with 128 members has 8,128 possible relations in it, where a relation is defined as an undirected path connecting two members through no intermediaries. The presence of a relation is indicated when a respondent names a person as an informal communicant. If a named person also acknowledges a relation with the respondent, we have a redundant, though reaffirming, piece of information on the presence of a relation. In the count of relations a reciprocal acknowledgment of communication produces one relation. The total number of such relations among the 128 faculty is 559.

⁴ See Crawford's (1970, p. 79) map of informal communication relations among scientists in sleep and dream research: I focused on the large network of 160 scientists and eliminated

The network of physical scientists will also be examined by department: department networks (which are zones within the whole network) will be characterized in terms of their density, compactness, and mesh and compared with one another. Finally, department networks will be decomposed into parts that roughly correspond to specialty groups, and the pattern of relations among these specialty groups will be examined. In combination with department literature on the research pursuits of their faculty, hierarchical-cluster analysis (Johnson 1967) proved to be an invaluable aid in defining clusters with fairly homogeneous research interests.⁵

The three characteristics of networks examined in this study are density, compactness, and mesh. Density is the most widely reported of various network characteristics. It is a measure of how nearly a network approaches

the network's peripheral members, i.e., those who have only one connection to the network. The effect of this elimination of peripheral members is to bias upward the density of Crawford's network. The other effect is to make the two networks, mine and Crawford's, equal in size: by an incredible coincidence the elimination reduced the size of her network to 128 members, the same size as mine. The exact wording of Crawford's questionnaire item is worth noting: "Are there scientists with whom you personally and frequently communicate information about your work in sleep and dream research? This does not include persons on a routine mailing list or student-teacher relationships, but individuals whom you often contact to discuss in a substantive way aspects of research or developments in this field, or to request an opinion. Please list all such persons whom you have contacted three or more times during the past year concerning your work in sleep and dream research" (p. 121). Aspects of Crawford's item may have led her respondents, in comparison with mine, to a more stringent interpretation of who were the appropriate persons to name as their communicants; furthermore, it should be recognized that I provided a list of persons for respondents to check and that Crawford requested her respondents to write in the names of their communicants. These features may have biased downward the density of Crawford's network relative to mine. At the same time, my network underrepresents the number of communication relations since it includes nonrespondents (Crawford's network consists entirely of respondents). I have no way of assessing the severity and direction of the overall bias that may be based on these and other differences between Crawford's and my methods. I am of the opinion, however, that the data are good enough to support a conservative interpretation, which is sufficient for my purposes.

⁵ In combination with department literature concerning the current research pursuits of faculty, the hierarchical-cluster analysis was helpful in making decisions about (a) combining memberships of several small specialty areas into larger groupings and (b) assigning faculty members with several specialty-group affiliations to one and only one group. The cluster analysis was performed on the networks of the departments of chemistry, physics, and geoscience where decisions of the foregoing sort were called for. The cluster analysis requires a measure of the proximity of pairs; I tested out various measures by taking the results of the cluster analysis to faculty members and asking them whether their being clustered with particular other faculty members made sense in terms of a commonality of research interest. I should like to report that considerable success was finally achieved with the following measure of proximity: $A(100) + B + (C/1,000)$, where A equals one if a pair is directly joined and zero if it is not, B equals the number of paths through one intermediary joining the pair, and C equals the number of paths through two intermediaries joining the pair. There are parallels between this measure of proximity and the one being used by citation analysts to define homogeneous clusters of research articles. Consult the author for more details.

the state in which each member is directly linked to every other member. Density is calculated as the ratio of observed to possible direct relations between persons in a network.⁶ With regard to a network's compactness and mesh, there are no conventions for measurement; accordingly, my use of them is briefly discussed.

Harary et al. (1965) distinguish between joining and reaching. The difference between the two is that joining ignores the direction of linkages while reaching does not. In a directed graph composed of arrows and points, one point is said to reach another if a path between them can be traced by following the direction of the arrows. In a general sense, joining refers to the existence of a connection. Both reaching and joining are accomplished in a certain number of steps: one step where there is a direct linkage, two steps where the linkage occurs through one intermediary, etc.

Accordingly, a network's compactness may be measured by calculating the cumulative proportion of the possible pairs of persons in a network that are joined, or reached, successively by one-step, two-step, three-step paths, and so on.⁷ When a substantial proportion of pairs in a network are joined by fairly short paths, a network is compact; it is more compact than another in which a smaller proportion of pairs are joined by paths of comparable length. For example, a network in which 80% of its possible pairs are joined by paths of one or two steps is more compact than a network in which only 30% of its pairs are joined by paths of one or two steps. Under some circumstances, one might also say that in the former network persons on the average reach 80% of the population through paths of one or two steps, whereas in the latter network persons on the average reach only 30% of the population through paths of one or two steps.⁸

The distinction between network compactness and mesh can be expressed most clearly in terms of "ego-anchored" networks. For each ego or point in a network one may produce a "tree" involving other members of the network and showing the shortest routes between himself and others. Ego's tree expresses graphically his reach in the population. In figure 1 ego reaches 18 points in four steps. If the total population of the network, from which ego's tree is isolated, consists of these 18 persons plus ego, then ego's four-step reach is 100%. The tree in figure 1 does not necessarily involve all the

⁶ Density equals $2A/N(N-1)$, where A equals the actual number of undirected links in a network and N equals the number of persons in the network.

⁷ Only the shortest paths which join pairs are considered in this calculation.

⁸ Average reach equals $(X_1 + X_2 + \dots + X_N)/N(N-1)$, where X_1, X_2 , etc., are the numbers of persons that each person is joined to by paths of a certain length and N is the size of the network. The proportion of joined pairs equals $2A/N(N-1)$, where A equals the number of pairs joined by paths of a certain length and N equals the size of the network. $A = (X_1 + X_2 + \dots + X_N)/2$ in networks that can be represented by a symmetric adjacency matrix.

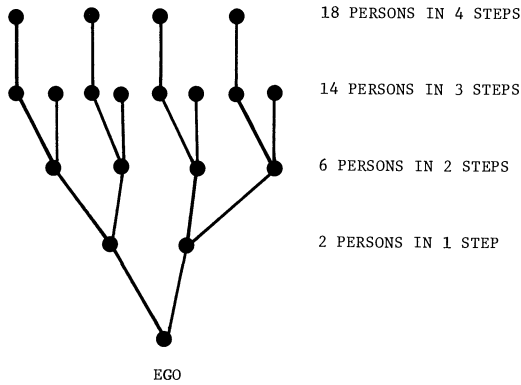


FIG. 1.—Graph of an ego's reach in a hypothetical network

connections present in a network, for members of ego's tree may be linked with one another; such links, however, are irrelevant in ascertaining ego's reach. It is from this standpoint that a distinction is made between reach and mesh. When there are many connections among members of ego's tree, his network is tightly meshed.

The measure of network mesh which I employ is based on the idea that a tightly meshed network is one in which pairs tend to be joined by multiple and preferably short paths. Accordingly, involved in the measure is the calculation of the average number of two-step paths which join the pairs that are joined by either one- or two-step paths. For example, if one- or two-step joined pairs of some hypothetical network are joined by an average of 10 two-step paths, whereas the one- or two-step joined pairs of another network are joined by an average of five two-step paths, the first network is defined as more tightly meshed than the second. Also, in order to assess a network's mesh, I calculated the number of three-step paths that on the average join all the pairs of a network that are joined by paths of three steps or fewer.⁹

The substantive implications of the distinction between network compactness and mesh are that, while reachability implies the opportunity for information transmission, the presence of multiple pathways implies a heightened probability of such transmission actually occurring.

SOCIAL NETWORK DENSITIES OF SEVERAL ACADEMIC DEPARTMENTS

Were the 559 communication relations in my sample distributed independently of department boundaries, 20% would have been intradepart-

⁹ In the enumeration of joining paths, redundant paths are excluded, i.e., paths in which the same element occurs more than once. Ross and Harary's (1952) algorithm for finding the number of nonredundant paths up to four steps in length was used for this enumeration.

mental. Instead, 60% of the relations occur inside the departments: three times as many as expected. Although communication relations tend to fall inside department boundaries, they do not uniformly do so: the six physical science departments vary from 18% to 69% in the density of communication relations inside them (see table 1). With the exception of the mathematics department, the rule is that the larger the department, the lower its network density. In other words, the absolute number of observed relations between department members does not increase in direct proportion to the number of possible relations: there is an inelasticity in the increase of the number of relations between department members as the total number of possible relations increases.

In figure 2 a line is drawn which shows the number of relations required to achieve a 70% density (approximately the density of the two smallest departments) as the number of potential relations increases. The dots in the figure show the actual position of the six departments relative to this requirement. To be sure, the number of relations among department members does increase with department size, but this increase is not sufficient to maintain in the larger departments the density found in the smaller departments and so becomes a decreasing function of department size.

A negative association between network density and size is, of course, what we would expect when considering networks whose sizes vary considerably, since in progressively larger networks it becomes less and less feasible for persons to maintain direct and regular contact with all the other members of the network. However, in this sample of departments the range in size is not extreme; hence the inelasticity in the amount of department relations is somewhat surprising. For the moment, a discussion of data which bear on the explanation of this inelasticity is postponed in order to address some of the consequences of variation in the departments' network density.

TABLE 1
CHARACTERISTICS OF SIX PHYSICAL SCIENCE DEPARTMENTS
WITHIN A UNIVERSITY

DEPARTMENTS	CHARACTERISTICS			
	Network Density* (%)	Size	Intra-departmental Relations	Survey Non-respondents
Statistics	69	9	18	5
Astronomy	66	10	29	2
Mathematics	21	21	33	11
Geoscience	33	22	69	7
Chemistry	31	25	80	10
Physics	18	41	109	22

* Network densities are adjusted for inequalities of survey response rate across departments.

CONSEQUENCES OF VARIATION IN DEPARTMENTAL NETWORK DENSITY

The greater the network density, the more compact is the social network inside departments. Figure 3 shows for each department the cumulative proportion of pairs that are joined by paths involving one-step, two-step, three-step, and four-step paths, respectively. The proportion of pairs joined by one-step paths is, of course, the network's density.¹⁰ The rank order of network densities corresponds to the compactness of department networks. Mathematics is again the exception to the rule. Astronomy and statistics have the most compact networks, since no person in them is separated from others by more than one intermediary. The geoscience and chemistry departments also have relatively compact networks: 75%–80% of the pairs in them are joined either directly or indirectly through one intermediary. Physics and mathematics have the least compact networks; only one-half of the pairs in physics are joined directly or through one intermediary, and in mathematics only slightly more than one-half of the pairs are joined by paths involving three intermediaries or fewer.

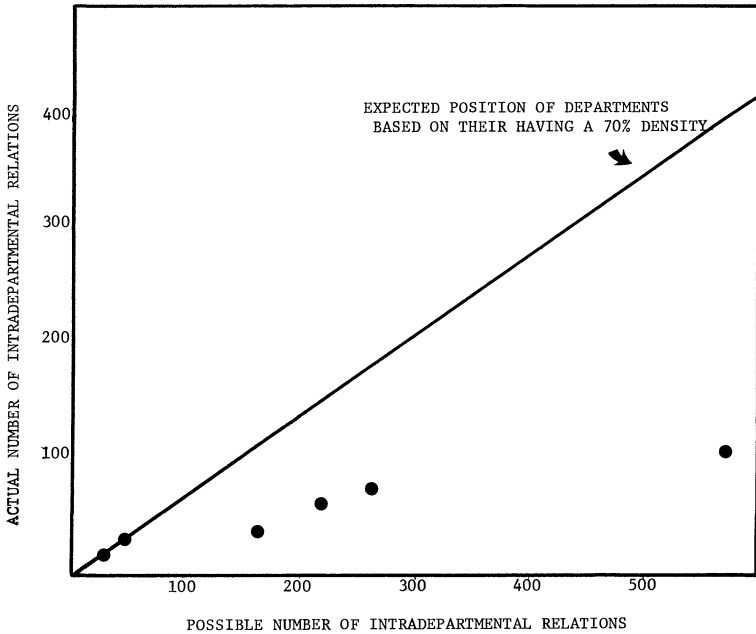


FIG. 2.—Inelasticity of increase in the amount of actual intradepartmental relations to increases in the amount of possible relations where the number of possible relations is adjusted for inequalities in the number of nonrespondent pairs.

¹⁰ These densities are not adjusted for inequalities of response rate across departments, unlike the densities reported in table 1.

The anomalous position of the mathematics department is accounted for by a segmentation of communication relations within the department. As figure 4 shows, the department is divided into two clusters of faculty, composed separately of applied and pure mathematicians, and not a single research relation joins them. It is this segmentation that has reduced both the density and the compactness of the mathematics network. Apart from the special case of a segmented network, the factor which determines a network's compactness appears to be simply the absolute amount of relations maintained within a network's population relative to the population's size.

In mathematics and in physics, which have the least compact and least dense networks, faculty pairs are joined by fewer paths than are faculty

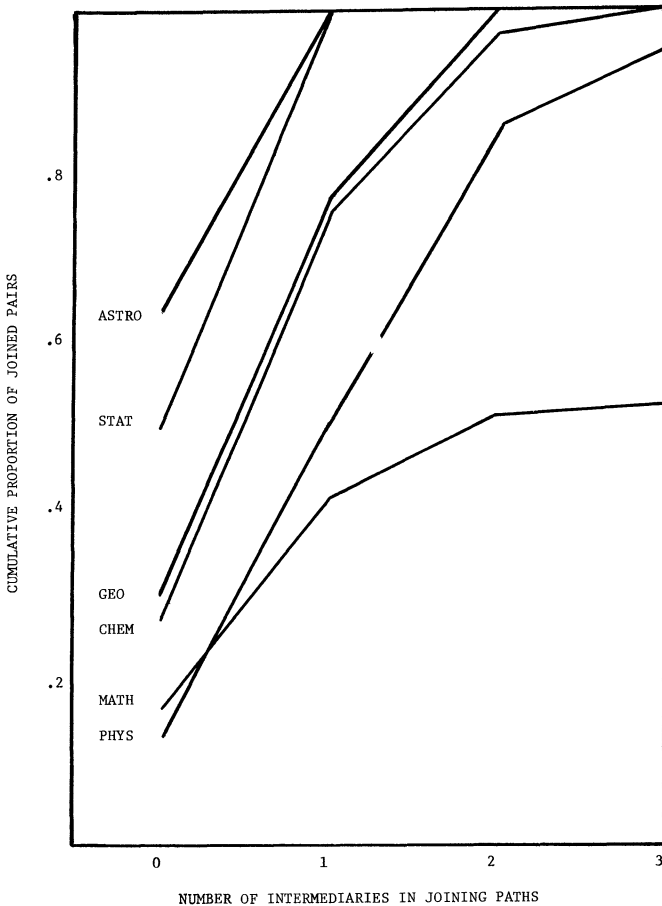


FIG. 3.—Compactness of department networks as measured by the cumulative proportion of pairs that are first joined by paths involving zero, one, two, and three intermediaries, respectively.

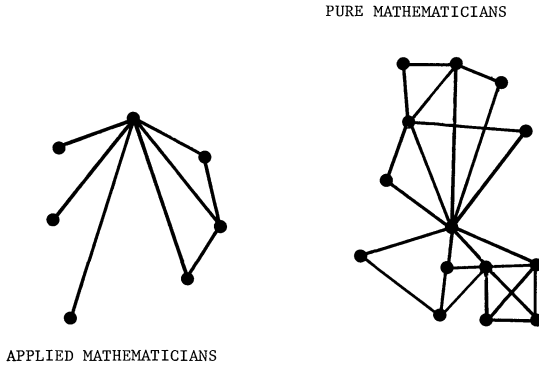


FIG. 4.—Segmentation in the mathematics department

pairs in the other departments. In mathematics, for example, pairs that are joined by one- or two-step paths are joined on the average by one two-step path, whereas in chemistry, pairs that are joined by one- or two-step paths are joined on the average by three two-step paths. The difference in mesh between the mathematics and chemistry networks appears more substantial when pairs joined by paths of three steps or fewer are considered; these pairs in chemistry are joined on the average by 16 three-step paths, whereas in mathematics such pairs are joined on the average by two three-step paths. These data and the comparable data for the other departments are shown in figure 5.

In the case of mathematics and chemistry, a difference in network density is positively related to a difference in network mesh. Similarly, the somewhat higher density of astronomy relative to statistics is positively related to the number of joining two-step paths—three in astronomy versus two in statistics—and this difference cascades into a substantial difference in the number of joining three-step paths: 14 in astronomy versus six in statistics. However, the mesh of statistics relative to chemistry, geosciences, and physics is unexpected; moreover, the slightly higher density of geosciences relative to chemistry is not associated with a higher number of joining paths. The relationship between network density and mesh, in other words, is not as neatly formulated as is the relationship between network density and compactness.

Additional parameters besides sheer density clearly enter into the determination of network mesh. In very small networks, for example, the absolute number of indirect paths of two or more steps is radically constrained; thus it is that in figure 5 astronomy and statistics, which have only 10 and nine members, respectively, are unable to maintain their higher mesh relative to the chemistry and physics departments when paths of three steps are considered.

Other factors affecting network mesh must affect the arrangement of relations in a network. In networks of comparable size, density, and compactness, different arrangements of relations would result in considerable differences in network mesh. But in suggesting that other factors besides density determine the mesh of a network, I do not mean to minimize the importance of the density factor. I believe, on the contrary, that differences of density must play a considerable role in determining mesh, but this role has not been adequately revealed by my data. The absolute number of communication relations relative to a network's size ought to place a constraint on the possible degree of mesh, and it must be within the context of such constraint that differences of pattern affect network mesh. In other

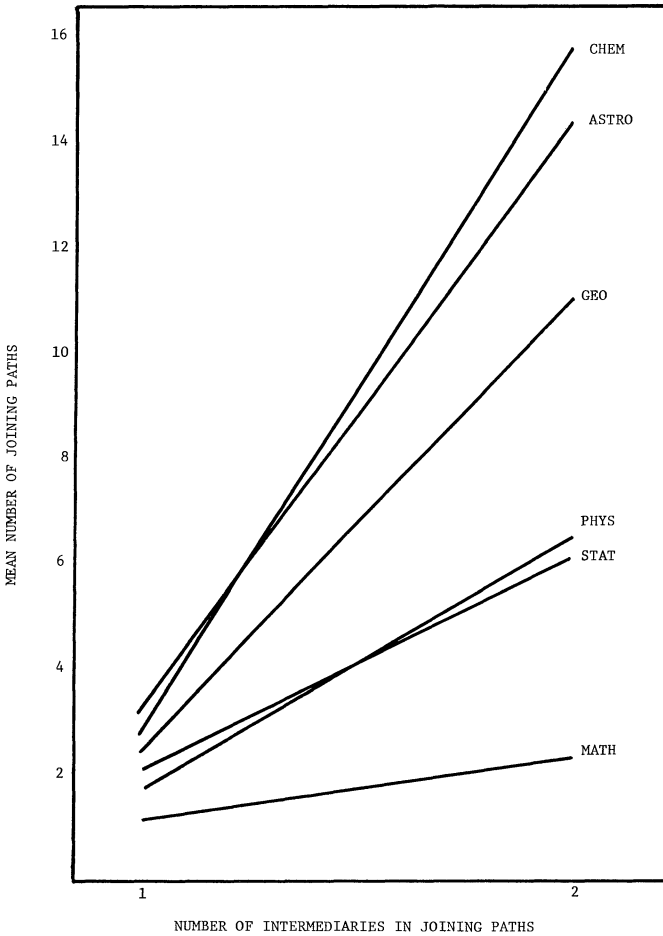


FIG. 5.—Mesh of department networks as measured by the mean number of paths of different length that join pairs.

words, one may presume that density (or the absolute number of relations between the members of a population relative to the population's size) remains the paramount factor in determining network attributes.

In this light, recall that the analysis has shown an inelasticity in the amount of intradepartmental communication relative to increases in the size of the departments. It is worthwhile, accordingly, to explain the basis of this inelasticity. The obvious explanation, which I shall explore, is that a large department does not necessarily provide more opportunities to its members for informal collaboration than a smaller department if the large department is composed of different research specialties.

SPECIALTY CLUSTERS INSIDE DEPARTMENTS

Figure 6 presents the sociograms of the astronomy and statistics departments; I suggest that these networks may be treated as two specialty clusters which happen to have department autonomy. I will show that the larger departments are simply collections of such clusters and that communication relations tend to fall inside clusters rather than inside departments: these twin features of department networks would account for the inelasticity of intradepartmental communication.

The presence of specialty clusters inside departments has already been

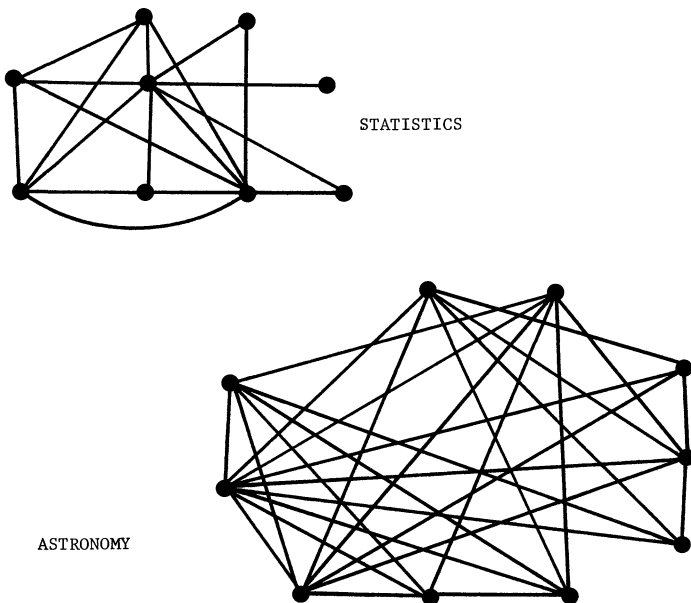


FIG. 6.—Social networks of the astronomy and statistics departments

shown in the case of mathematics where two clusters were described, composed separately of applied and pure mathematicians. Since not a single communication relation joins the two clusters, affiliation with the same department is clearly not in itself a sufficient condition for a social network to extend throughout a department's membership.¹¹ The segmentation which is seen in mathematics does not occur in any of the other departments and is probably a rare phenomenon; I suspect that research pursuits of department members typically overlap to generate networks without segmentation.

With hierarchical cluster analysis plus department literature about the research pursuits of faculty members, clusters of faculty having fairly homogeneous research interests were defined. Three clusters were defined in chemistry corresponding to (1) geochemistry, nuclear, and cosmochemistry; (2) physical chemistry and chemical physics; and (3) organic, inorganic, and biological chemistry. Five clusters were defined in physics corresponding to the research areas of (4) high-energy physics, (5) solar physics, (6) atomic and molecular physics, (7) astrophysics, and (8) solid state physics. Three clusters were defined in geoscience corresponding to the areas of (9) paleontology and stratigraphy, (10) fluid dynamics, and (11) a conglomeration consisting of geochemistry, geology, mineralogy geophysics, and crystallography. Including (12) astronomy and (13) statistics, as well as the two clusters in mathematics, all but one of the 128 faculty members were uniquely assigned to one of 15 specialty clusters.

Figure 7 plots the network densities of the specialty clusters (denoted on the figure by stars) and the cluster interfaces (filled or empty circles) against the number of possible relations in a cluster or at a cluster interface. Cluster interfaces consist of pairs of faculty who belong to different clusters. There are two types of interfaces: those, denoted on the figure by empty circles, which involve two clusters from the same department (e.g., in the physics department, the interface of solid state and high-energy physics) and those, denoted on the figure by filled circles, which involve two clusters from different departments (e.g., the interdepartmental interface of the physical chemistry and the solid state physics clusters).

Figure 7 makes two statements. First, with the exception of one specialty cluster (pure mathematicians), all the network densities of the clusters are higher than the densities of the cluster interfaces. In other words, communication relations tend to fall inside the clusters. Second, the densities of intradepartmental cluster interfaces are not consistently higher than the

¹¹ I should perhaps underscore the fact that this study deals with research relations. Consequently the segmentation which occurs in terms of these mathematicians' research interests does not necessarily occur in their nonprofessional associations with one another.

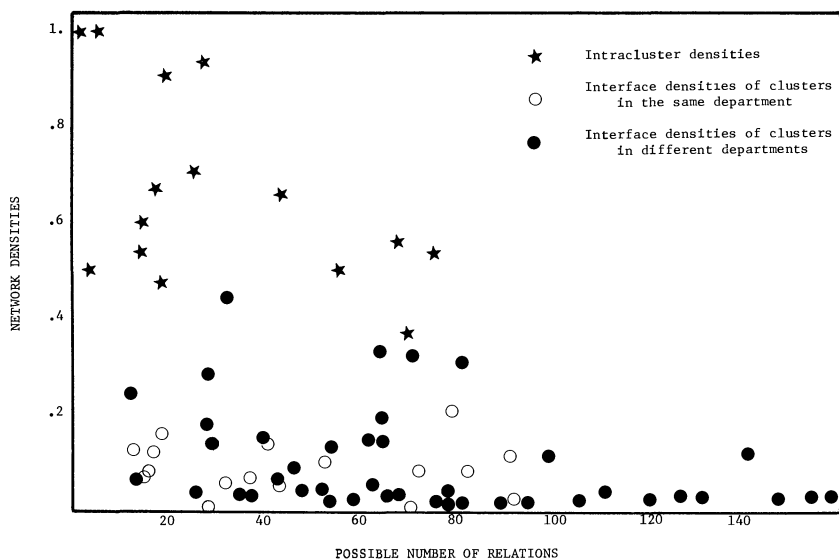


FIG. 7.—Network densities of research clusters and their interfaces controlling for possible number of relations where the number of possible relations is adjusted for inequalities in the number of nonrespondent pairs. Excluded from the figure are 46 densities that are interface densities of clusters in different departments and that have density values of zero.

densities of the interdepartmental cluster interfaces. Indeed, the six highest interface densities involve clusters from different departments. This suggests that department boundaries have little effect on the pattern of intercluster relations.

There thus appears to be a distinctive framework of research relationships among the physical scientists. That is to say, there are nodes in the network which are composed of faculty in the same department who have similar specialty interests and which are constituted by a greater thickening of interpersonal research relationships relative to the background network of these relationships (see the observed tendency for research relations to occur between members of the same specialty). Among the nodes there are certain major lines of interaction; these major interactions involve faculty who belong to different departments and are constituted (like the nodes themselves) by a greater thickening of research relationships relative to the background network (see the observed tendency for the relationships to fall on the interdepartmental rather than the intradepartmental interfaces). In sum, it appears that the physical science sector of this university may be conceived simply as composed of specialty clusters inside of which research communications tend to occur and which are interrelated with one another independently of department boundaries.

MULTIDISCIPLINARY INTEGRATION INSIDE THE UNIVERSITY

While almost half (48%) of the total number of research relationships fall within the specialty clusters, only 12% of the relationships occur between the specialty clusters of the same department. A substantial amount (39%) of the research relationships in the network are interdepartmental. The major framework of research relationships—consisting of the specialty clusters and the six strongest interdepartmental cluster interfaces—accounts for 65% of the total number of the relationships. There is, in other words, a substantial number of crosscutting research ties in this network: 23% of the total number of ties not only crosscut department boundaries, but also crosscut the main lines of research interaction between the specialties of different departments.¹² These data suggest a basis of structural cohesion in academic communities that is more inclusive than the departmental units Blau has considered. Accordingly, an explanation is proposed on the issue of how parameters of university organization may foster a multidisciplinary integration based on structurally cohesive research networks.

In a massive and decentralized scientific enterprise such as exists in the United States, a large portion of scientists' professional contacts inevitably involve persons who are outside the organizations where they are located. Nevertheless, the larger and the more heterogeneous the body of active researchers within a university, the greater will be the absolute amount of intra- and interdisciplinary exchange occurring within it: when two fields of science are joined by a sharing of techniques, this connection can be manifested inside the universities that support scientists in both fields. In universities that support active researchers in many fields, a host of such connections between fields can be manifested. The larger the average size of the fields inside a university, the greater should be the absolute number of opportunities for research exchange. The formulation above is hardly problematical.

What is problematical is the amount of absolute increase in research exchange that we can expect to occur with increases in the average field size and the diversity of fields inside a university: the formation of a compact and tightly meshed multidisciplinary research network within a large university would require the occurrence of a considerable amount of exchange among its faculty. Accordingly, I would like to suggest something in addition to the idea that the average faculty member of a large heterogeneous university will less frequently have to go outside his university to find research colleagues and technical resources than will the faculty members of smaller, more homogeneous universities.

¹² Intracluster relations (269), relations on intradepartmental interfaces (69), relations on the six strongest interdepartmental interfaces (93), relations on the weaker interdepartmental interfaces (126), relations of the faculty member who was not assigned to a cluster (2), total: 559 relations.

University social structure may foster the production of a structurally cohesive research network among its faculty by conditioning the choice of those colleagues to whom faculty members go for advice and technical resources. Hypothetically, what is the probability that a scientist who is seeking a particular resource will go to the one faculty member on his own campus who possesses it, if nine other scientists scattered about the country also possess the resource? Usually, I suspect that the probability would be more substantial than one in 10, that is, that the attractiveness of potential suppliers of scientific resources would vary according to whether they are located inside or outside the same university.

Geographical proximity is, of course, one factor that might underlie the preferential selection of fellow faculty as exchange partners, for collaboration between persons who are in close proximity is often more convenient than long-distance collaborations. Even though long-distance collaboration is feasible, closer tabs can be kept on the progress of research and the motivations of its participants in short-distance collaborations. The advantages of short-distance collaboration, which are probably fairly trivial under "normal" circumstances, may become considerable when the research problem that is the subject of a collaboration is of a nonroutine nature or when competitive pressure is severe.

The culture of a university is an additional factor that might underlie the preferential selection of fellow faculty members as research-exchange partners. A scientist going to a fellow faculty member may be more sure of the response he will get to his request for advice or resources, for shared university citizenship often entails a tacit obligation of receptiveness, if not compliance, to requests for assistance from within the community. Furthermore, persons within the same faculty may be preferred as informal collaborators because they can usually be trusted to guard the crystallizing ideas involved in tooling up for a research project. While scientists with research in progress need not in general be secretive (cf. Hagstrom 1967), they have possibly a greater need of secrecy during the initial stages of a research project: if a scientist can establish a lead on his potential competitors, it is unlikely that they will be willing to commit the resources and energy required to catch up to him (unless of course the problem is considered worth the risk or they believe that the leader's approach is in error). The culture of a university—the strength of which is reinforced by a university community's capacity to impose, if need be, social and material penalties on deviants from its culture—makes the university a place where new ideas and technologies can be explored and developed with relative ease and security.

In sum, I have argued not merely that a university is a place where research exchange occurs more or less frequently depending on the uni-

versity's size but that it further promotes the amount of exchange among its faculty by presenting a field of opportunities that, for a variety of reasons, powerfully intervenes (see Stouffer 1940) between a member of its science faculty and other opportunities existing elsewhere.

An important issue still remains: that is, even if we accept the pertinence of this intervening-opportunities formulation, to what degree can we expect university social structure to promote the cohesiveness of a multidisciplinary research network? Is the overall effect of university social structure trivial, or can it promote a high level of cohesiveness?

While I cannot provide a definitive answer to this question, I do find that, taken as a whole and in comparison with an equally large network of researchers communicating about problems in a single specialty (Crawford 1970), the physical science network is more compact and tightly meshed (see table 2). Persons in the physical science network are on the average joined to 40% of their fellows by one- or two-step paths, whereas persons in the sleep-research network are joined on the average to 18% of their fellows. Pairs of researchers who are joined by one- or two-step paths in the physical science network are joined by an average of two two-step paths, whereas in the sleep-research network such pairs are joined by an average of one two-step path. The difference in the two networks' mesh appears more pronounced when longer paths between joined pairs are dealt with.

Thus, on the basis of the measures utilized in this study, the communication network of a diversely specialized population of physical scientists is more structurally cohesive than one composed of more homogeneously specialized scientists. Specialization per se does not appear to constrain automatically and severely the possible degree of structural cohesion (see Durkheim 1933). These data suggest, therefore, that settings may exist in science where a fairly high degree of multidisciplinary integration is systematically fostered and that the research-oriented universities provide likely sites of such integration.

TABLE 2
COMPACTNESS AND MESH OF THE PHYSICAL SCIENCE AND SLEEP
RESEARCH NETWORKS

NUMBER OF INTERMEDIARIES IN JOINING PATHS	CUMULATIVE PROPORTION OF JOINED PAIRS (%)		MEAN NUMBER OF JOINING PATHS	
	Physical Scientists	Sleep Research	Physical Scientists	Sleep Research
None	7	4
One or less	40	18	2.3	1.4
Two or less	76	47	13.9	3.2
Three or less	96	75	134.0	11.9

CONCLUSION

I believe that universities of the type examined here are in general good places to find structurally cohesive multidisciplinary research networks. To be sure, the university chosen as the setting of this research is unlike other universities in important respects. It is one of a small set of prestigious universities that are able to carry out doctoral training and to support distinguished faculty in each of the central fields of scientific training and research. Moreover, this university differs in important ways from the majority of the most prestigious universities. It is not as large as many of these universities, and it has institutionalized arrangements, particularly among its physical science faculty, that purportedly foster an unusual amount of interdisciplinary communication.¹³ In other words, there are few other settings in which the occurrence of a cohesive multidisciplinary research network is more likely. If, therefore, such a network is not present in the physical science sector of this university, I believe that it will not be found with substantial frequency elsewhere (that is to say, a negative finding in this setting can be taken as presumptive evidence against the occurrence of structurally cohesive multidisciplinary research networks elsewhere). Of course a single positive finding may not be generalized: the finding of a cohesive network among the physical science faculty of this university does not imply that equally cohesive networks are to be found elsewhere. Accordingly, while keeping in mind that this university's network could be unique with respect to its morphological attributes, I suggest that parameters which are common to university organization may be more influential than idiosyncrasies of university organization in determining the structural cohesiveness of the research network that I have examined. Whether such is the case is a matter for further empirical investigation. It is to be hoped that this study warrants further research designed to elaborate or refute my findings and proposals.

I should like to close by suggesting the outlines of a broader viewpoint on the occurrence of cohesive multidisciplinary research networks inside universities. The production of these networks inside the universities where the membership of the scientific elite is concentrated is possibly not as problematical as is the production of a cohesive network composed of these

¹³ It falls outside the feasible, and intended, scope of this paper to assess the significance of those factors which may uniquely distinguish this university from others. The thrust of the paper is to point to the existence of a structurally cohesive multidisciplinary research network within a university community and to describe this network's morphology. The presence and structure of the network have been interpreted on the basis of parameters which are common in university organizations. In so doing, I have sought to open further the door which Peter Blau (1973) has pried open for the large-scale network studies which will be necessary in order to assess accurately the variety of factors, and their relative importance, which affect the pattern of informal relations among university faculty.

concentrations of the elite at different universities. That is, the presence of cohesive multidisciplinary networks within the elite universities, although probably a necessary condition, is not a sufficient condition for a structurally cohesive interorganizational network that involves the total (or a substantial fraction) of the basic science elite. To be sure, evidence of various studies of invisible colleges suggests that the members of the elite within the same discipline or specialty keep in touch with one another regardless of their geographical location. Consequently, these invisible-college associations should be a basis of connectivity among university communities. But it is reasonable to suspect that, as the American academic system has become more massive and decentralized, the interorganizational network which involves the scientific elite has become progressively less compact and tightly meshed. If such is the case, then alongside Ben-David and Zloczower's argument concerning the benefits of academic decentralization with respect to scientific innovation (Ben-David 1960; Ben-David and Zloczower 1962) there might be placed a complementary argument about the costs of academic decentralization with respect to the social cohesion of the scientific elite.

Some initial steps toward such an argument have already been taken by Mulkay (1976), who suggests that the concentration of the British scientific elite in a few universities has fostered their cohesion and, in turn, their ability to resist governmental threats to scientific autonomy. While, as Mulkay suggests, a cohesive elite may be of importance in considering science's relationship to polity, I should also think that a cohesive elite is of importance in considering the internal affairs of science. The present paper, however, is not the place to engage this controversial issue of whether a cohesive scientific elite (composed of the elites of different scientific fields) is a phenomenon of importance to science. But this issue clearly merits further study. Especially now—when questions about the equitable distribution of scientific resources are compelling attention—we ought forcefully to address the issue of on what bases, if any, it is important to maintain universities that are centers of excellence across a broad range of scientific fields and the issue of whether the further decentralization of the scientific elite is a process which will have significant negative consequences for the scientific institution.

REFERENCES

- Barnes, J. A. 1972. *Social Networks*. Addison-Wesley Modular Publications, module 26. Reading, Mass.: Addison-Wesley.
- Ben-David, Joseph. 1960. "Scientific Productivity and Academic Organization in Nineteenth Century Medicine." *American Sociological Review* 25 (December): 828-43.
- Ben-David, Joseph, and Awhraham Zloczower. 1962. "Universities and Academic Systems in Modern Society." *European Journal of Sociology* 3 (1): 45-84.
- Blau, Peter M. 1973. *The Organization of Academic Work*. New York: Wiley.

American Journal of Sociology

- Bott, Elizabeth. (1957) 1971. *Family and Social Network: Roles, Norms and External Relationships in Ordinary Urban Families*. London: Tavistock.
- Breiger, Ronald L. 1976. "Career Attributes and Network Structure: A Blockmodel Study of a Biomedical Research Specialty." *American Sociological Review* 41 (February): 117-35.
- Campbell, Donald T. 1969. "Ethnocentrism of Disciplines and the Fish-Scale Model of Omniscience." Pp. 328-48 in *Interdisciplinary Relationships in the Social Sciences*, edited by M. Sherif and C. W. Sherif. Chicago: Aldine.
- Cole, Stephen, and Jonathan R. Cole. 1968. "Visibility and the Structural Bases of Awareness of Scientific Research." *American Sociological Review* 33 (June): 397-413.
- Coleman, James S., Elihu Katz, and Herbert Menzel. 1966. *Medical Innovation: A Diffusion Study*. Indianapolis: Bobbs-Merrill.
- Crane, Diana. 1969. "Social Structure in a Group of Scientists: A Test of the 'Invisible College' Hypothesis." *American Sociological Review* 34 (June): 335-52.
- . 1972. *Invisible Colleges: Diffusion of Knowledge in Scientific Communities*. Chicago: University of Chicago Press.
- Crawford, Susan. 1970. "Informal Communication among Scientists in Sleep and Dream Research." Ph.D. dissertation, University of Chicago.
- Durkheim, Émile. 1933. *The Division of Labor in Society*, translated by George Simpson. New York: Free Press.
- Festinger, Leon, Stanley Schachter, and Kurt Back. 1950. *Social Pressures in Informal Groups: A Study of Human Factors in Housing*. New York: Harper.
- Gaston, Jerry. 1973. *Originality and Competition in Science: A Study of the British High Energy Physics Community*. Chicago: University of Chicago Press.
- Granovetter, Mark. 1973. "The Strength of Weak Ties." *American Journal of Sociology* 78 (May): 1360-80.
- . 1974. *Getting a Job: A Study of Contacts and Careers*. Cambridge, Mass.: Harvard University Press.
- . 1976. "Network Sampling: Some First Steps." *American Journal of Sociology* 81 (May): 1287-1303.
- Griffith, Belver C., Marilyn J. Jahn, and A. James Miller. 1971. "Informal Contacts in Science: A Probabilistic Model for Communication Processes." *Science* 173 (July): 164-66.
- Griffith, Belver C., and A. James Miller. 1970. "Networks of Informal Communication among Scientifically Productive Scientists." Pp. 125-40 in *Communication among Scientists and Engineers*, edited by Carnot E. Wilson and Donald K. Pollack. Lexington, Mass.: Heath.
- Griffith, Belver C., and Nicholas C. Mullins. 1972. "Coherent Social Groups in Scientific Change." *Science* 177 (September): 959-64.
- Hagstrom, Warren O. 1967. "Competition and Teamwork in Science." Final Report to the National Science Foundation. Mimeographed. Madison: University of Wisconsin.
- Harary, Frank, Robert L. Norman, and Dorwin Cartwright. 1965. *Structural Models: An Introduction to the Theory of Directed Graphs*. New York: Wiley.
- Johnson, Stephen C. 1967. "Hierarchical Clustering Schemes." *Psychometrika* 32 (September): 241-54.
- Kerckhoff, Allan C., Kurt W. Back, and Norman Miller. 1965. "Sociometric Patterns in Hysterical Contagion." *Sociometry* 28 (March): 2-15.
- Laumann, Edward O. 1973. *Bonds of Pluralism: The Form and Substance of Urban Social Networks*. New York: Wiley.
- Laumann, Edward O., and Frank U. Pappi. 1976. *Networks of Collective Action: A Perspective on Community Influence Systems*. New York: Academic Press.
- Merton, Robert K. 1968. *Social Theory and Social Structure*. New York: Free Press.
- Mitchell, J. Clyde, ed. 1969. *Social Networks in Urban Situations*. Manchester: Manchester University Press.
- Moreno, Jacob L. 1934. *Who Shall Survive?* Washington, D.C.: Nervous and Mental Disease.

- Mulkay, Michael J. 1976. "The Mediating Role of the Scientific Elite." *Social Studies of Science* 6 (September): 445-70.
- Mulkay, M. J., G. N. Gilbert, and S. Woolgar. 1975. "Problem Areas and Research Networks in Science." *Sociology* 9 (May): 187-203.
- Mullins, Nicholas C. 1966. "Social Networks among Biological Scientists." Ph.D. dissertation, Harvard University.
- . 1968. "The Distribution of Social and Cultural Properties in Informal Communication Networks among Biological Scientists." *American Sociological Review* 33 (October): 786-97.
- . 1972. "The Development of a Scientific Specialty: The Phage Group and the Origins of Molecular Biology." *Minerva* 10 (January): 51-82.
- Polanyi, Michael. 1962. "The Republic of Science: Its Political and Economic Theory." *Minerva* 1 (Autumn): 54-73.
- Price, Derek J. de S., and Donald de B. Beaver. 1966. "Collaboration in an Invisible College." *American Psychologist* 21 (November): 1011-18.
- Riley, Matilda White, and Richard Cohn. 1958. "Control Networks in Informal Groups." *Sociometry* 21 (March): 30-49.
- Ross, Ian C., and Frank Harary. 1952. "On the Determination of Redundancies in Sociometric Chains." *Psychometrika* 17 (June): 195-208.
- Stouffer, Samuel A. 1940. "Intervening Opportunities: A Theory Relating Mobility and Distance." *American Sociological Review* 5 (December): 845-67.
- Whitten, Norman, E., Jr., and Alvin W. Wolfe. 1973. "Network Analysis." Pp. 717-46 in *Handbook of Social and Cultural Anthropology*, edited by John J. Honigmann. Chicago: Rand McNally.