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ABSTRACT

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TECHNOLOGY TRANSFER TO DEVELOPING COUNTRIES: THE INTERNATIONAL TECHNOLOGICAL GATEKEEPER

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A questionnaire was developed and administered to the research personnel of An Foras Taluntais, the Irish agricultural research and development organization, to study the operation of communications channels for the international transfer of technological information. The techniques employed are similar to those used in previous studies of the purely domestic flow of technological information into American research and development laboratories.

The international transfer of technology, like domestic transfer, takes place in a two-step process operation through intermediary agents called technological gatekeepers. For greatest effectiveness such technological gatekeepers must be well integrated into two information networks -- an external network of information sources and an internal network of users to whom the information can be delivered. Possible strategies for gatekeeper development are discussed.

A great deal of attention has been devoted during the past decade to the problems of economic development and to the implications of the so-called "information explosion" in science and technology. Far less consideration, however, has been given specifically to the point at which these two areas intersect.

The problem posed by this intersection can be stated quite simply. A massive body of technical information exists in the world, and it continues to multiply and accumulate at a rapid pace. To reap greatest benefits, the developing country must select and apply this technology efficiently, however.

How, then, does the scientist or engineer working in a developing country with modest resources isolate and identify those pieces from the vast reservoir of the world's accumulated technical knowledge that are relevant to his current work? How, indeed, can he even discover whether his particular problem has already been solved by a researcher in another country? Surely limited R&D budgets can be applied more efficiently if existing solutions to current technical problems and new advances in research techniques can be communicated to those abroad who need them, rather than having to "discover" them over and over again in each separate country.

Many authors have already pointed out that all research and development suffers from its inability to answer these questions. But the symptoms are likely to be much more acute in a small country with limited resources. Such a country can ill afford duplication of research. So it is important to consider how scientific and technological information flows between countries, and how we may improve the communications channels that carry information from research groups in one country and deliver it to research groups in another (particularly a developing) country.

INTER-ORGANIZATIONAL TRANSFER OF TECHNOLOGY

Before examining the channels used in international technology transfer, it will be useful to look at an analogous situation which is somewhat better understood. The large, technology-based firm faces a problem very similar to that of the small country. No single organization can be technologically self-sufficient; it must always import relevant technology, and its effectiveness in doing this may be a key factor in the organization's success (2).

Most attempts to describe how new technology enters the firm have assumed a straight-forward model of information flow. According to this model, the interface between technical personnel in the firm and the external technical environment is a simple and direct one; each member of the organization accomplishes this interface in exactly the same way: he reads the literature, and he talks with people outside of the firm. To promote technology transfer under the terms of this model, all one must do is increase the degree and ease of contact between organization members and the two external information sources.

Although in theory this is very simple, in practice it often becomes very costly and is frequently ineffective. Indeed, research now shows that neither of these sources has been successful in providing information to the average industrial scientist or engineer. The literature is ineffective because the average engineer makes very little use of it -- particularly that contained in professional engineering and scientific journals -- and increasing its quantity will be ineffective because he already feels swamped by written material (3). Though it may occur frequently, direct contact with people outside of the organization is ineffective; studies have shown a consistent negative correlation between the use of this information source and the user's performance (4). The channel is a "noisy" one, subject to misinterpretation, and is, therefore, an ineffective medium for technology transfer (5).

There is only one information source whose use has consistently shown a positive correlation with technical performance. It lies not outside the firm, but within. Certain colleagues of the information-seeker within his own organization prove to be the most effective direct source of information. These colleagues, highly regarded as internal consultants, are shown to make significantly greater use than their associates of the professional and scientific journals and to maintain ongoing informal contact with many colleagues in other organizations, particularly university and non-profit laboratories (6). They thus serve as intermediaries between the average member of the firm and external sources of information, and we have given them the name "technological gatekeepers".

The technological gatekeeper receives information from a wide variety of sources external to his organization and acts as an information source for his colleagues in the laboratory. Such a two-step flow seems to be significantly more effective in transferring technology than a simple, direct connection from source to receiver. In at least some organizations, gatekeepers have actually developed a network among themselves to extend considerably the range of contact between organization members and sources of information in the world at large (7).

A similar phenomenon has been shown to play an important role in communications over a wide spectrum of human effort including the adoption of hybrid seed corn by farmers (8), the prescribing of new drugs by doctors (9), and the spread of political opinions among the electorate (10). It is not surprising, therefore, that the same two-step process has now been suggested in connection with technology transfer among nations.

As a first step in studying such international communication, we have made an empirical analysis of the way in which foreign agricultural information is acquired by one small country and then disseminated among its agricultural scientists. This study hypothesizes that communications channels for the international

transfer of technical information will also demonstrate a two-step flow process and that "international technological gatekeepers" can be isolated and identified as key intermediaries through which information from abroad is channelled and distributed.

The sample population in our study comprised the native-born personnel (11) of An Foras Taluntais (A.F.T. - the Irish Agricultural Institute), including research personnel and first- and second-line supervisors -- but not technicians. Those who reported spending less than 10 percent of their time on research and development were also removed from the sample.

An Foras Taluntais operates under a charter similar to that of many other government-supported research institutes. One of its primary goals is the acquisition of information to promote agricultural innovation as a means toward the economic and social development of the nation. It therefore acts in one sense as a gatekeeping institution, mediating between the Irish farmer and agricultural developments occurring both within and outside of the country.

An Foras Taluntais is divided into six divisions. Each division is further subdivided into several departments (Glasshouse Crops and Mushrooms, Meat Research, Pig Husbandry, etc.). Each department may be spread over several geographic areas and, furthermore, sections of several separate departments may be lumped into a single research center. The research personnel of A.F.T. are overwhelmingly Irish by nationality (95 percent are citizens of the Republic of Ireland or Northern Ireland). The sample population of 170 scientists contained 55 Ph.D.'s; most of the remaining held a degree or certification higher than the bachelor's level. Our study was based on a brief questionnaire administered to all scientists in An Foras Taluntais. In addition to the usual demographic and biographic questions, the respondents were asked to name the people both within and outside of A.F.T. with whom they most frequently communicated on scientific

matters, and to estimate the intensity of their foreign correspondence over the past year. The questionnaire enjoyed an 85% response.

Choosing International Gatekeepers

To be an effective gatekeeper in an international sense an individual must be well integrated into two networks: an external network of foreign information sources and an internal network of domestic users to whom the required information can be delivered.

The structure of the internal communication network can be approximated by examining the responses to the question in which "most frequent" scientific discussion partners are named. Each respondent is thus connected to those whom he names. The diagram of such responses (Figure 1) exposes for each person the number of entering branches -- as an index of the number of people who turn to a given individual for information, or the number of people who can potentially be reached by information held by that person. A person with a large number of entering branches is likely to be a very important source of information for his colleagues in the organization; we call him, for purposes of the present study, a "communication star" (13). Numbers 14, 15, 20, and 28 are communication stars in the figure.

For such a "communication star" to also be a "technological gatekeeper" he must be well integrated into an external network of foreign information sources; he must use the network regularly, and his network must be broad enough to include a diversity of such foreign sources. Two criteria -- the frequency of foreign technical correspondence and the frequency of foreign scientific and professional meeting attendance -- were used. Each of these channels can be used frequently, and each allows contact with a large number of overseas colleagues. The degree to which they are used is therefore judged to be a good measure of integration into the external network.

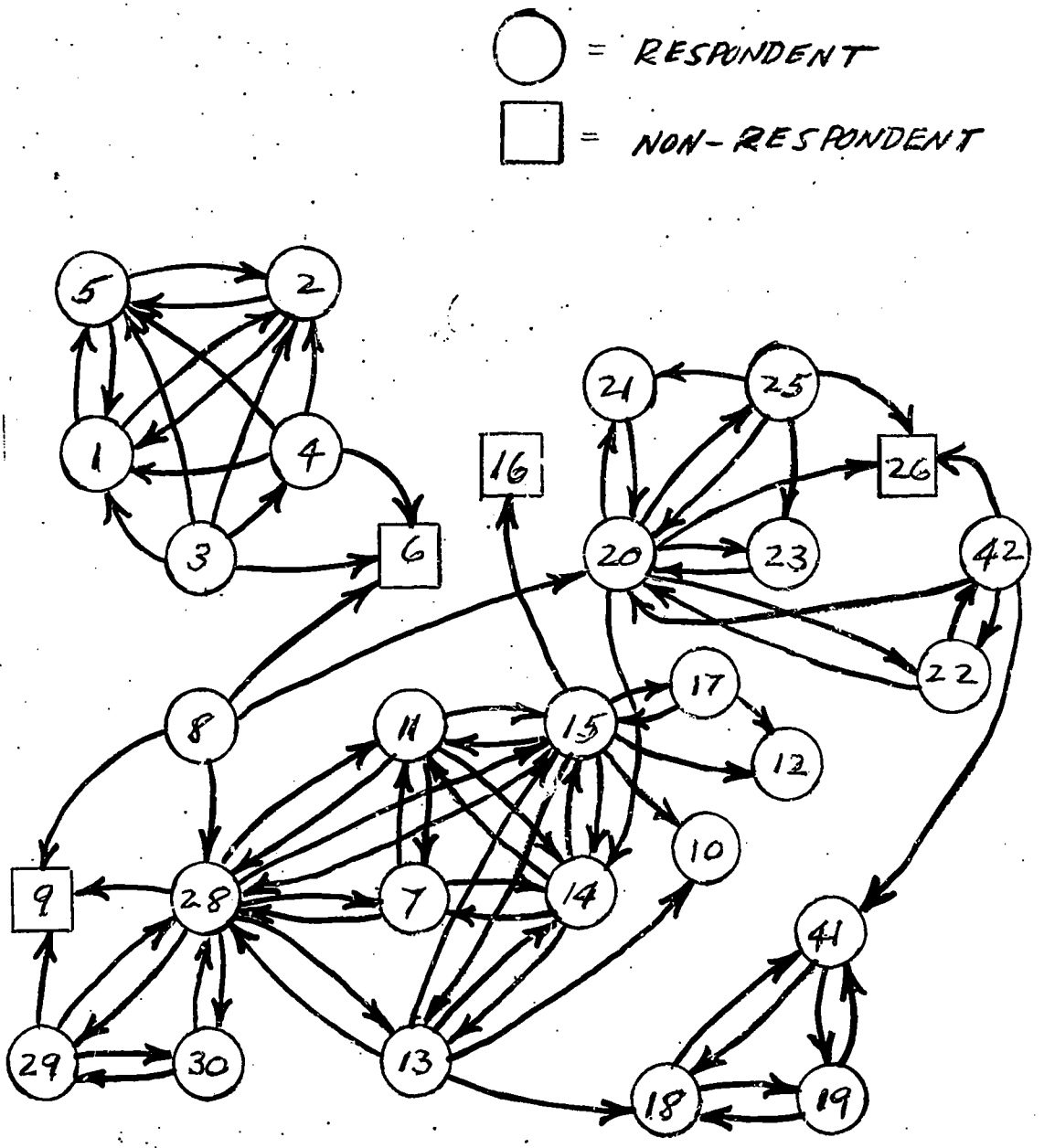


FIGURE 1. PARTIAL SCHEMATIC OF THE A.F.T. COMMUNICATION NETWORK (ONE RESEARCH CENTER)

The concept of the "technological gatekeeper" can be proved operative if it can be demonstrated that the "communication stars" actually do receive a greater amount of foreign information than do their colleagues. If each individual were to receive most of his foreign technical information directly from its source (direct flow), the gatekeeper concept would be meaningless. Similarly, if the high international communicators were isolates within their country, the gatekeepers would be non-existent. Simply states, a single individual must be instrumental in both the acquisition and dissemination of foreign information.

In fact, the data show that technical discussion stars actually do receive significantly more international technical information than non-stars as measured by frequency of foreign correspondence and attendance at foreign acientific and professional society conferences (Figure 2). They also read a significantly greater number of foreign journals (14). The gatekeeper hypothesis is quite strongly supported.

In addition to his communication activity, the international gatekeeper displays somewhat greater technical competence than his non-gatekeeper colleagues. Those in A.F.T. are, on the average, significantly superior to their colleagues in both publications and patents, and a higher proportion have a Ph.D. degree. Technical performance is extremely difficult to measure, but to the extent that publication of scientific and professional papers and the acquisition of patents serves as an indicator, the international gatekeeper is a high performer indeed.

THE GATEKEEPER NETWORK

Recent studies (15) show that in American research laboratories gatekeepers often develop tightly connected networks of their own within each laboratory's communications network. Such a gatekeeper network provides an effective mechanism for coupling the laboratory to outside events. The average engineer or scientist now has more than just a single intermediary to provide him with outside information;

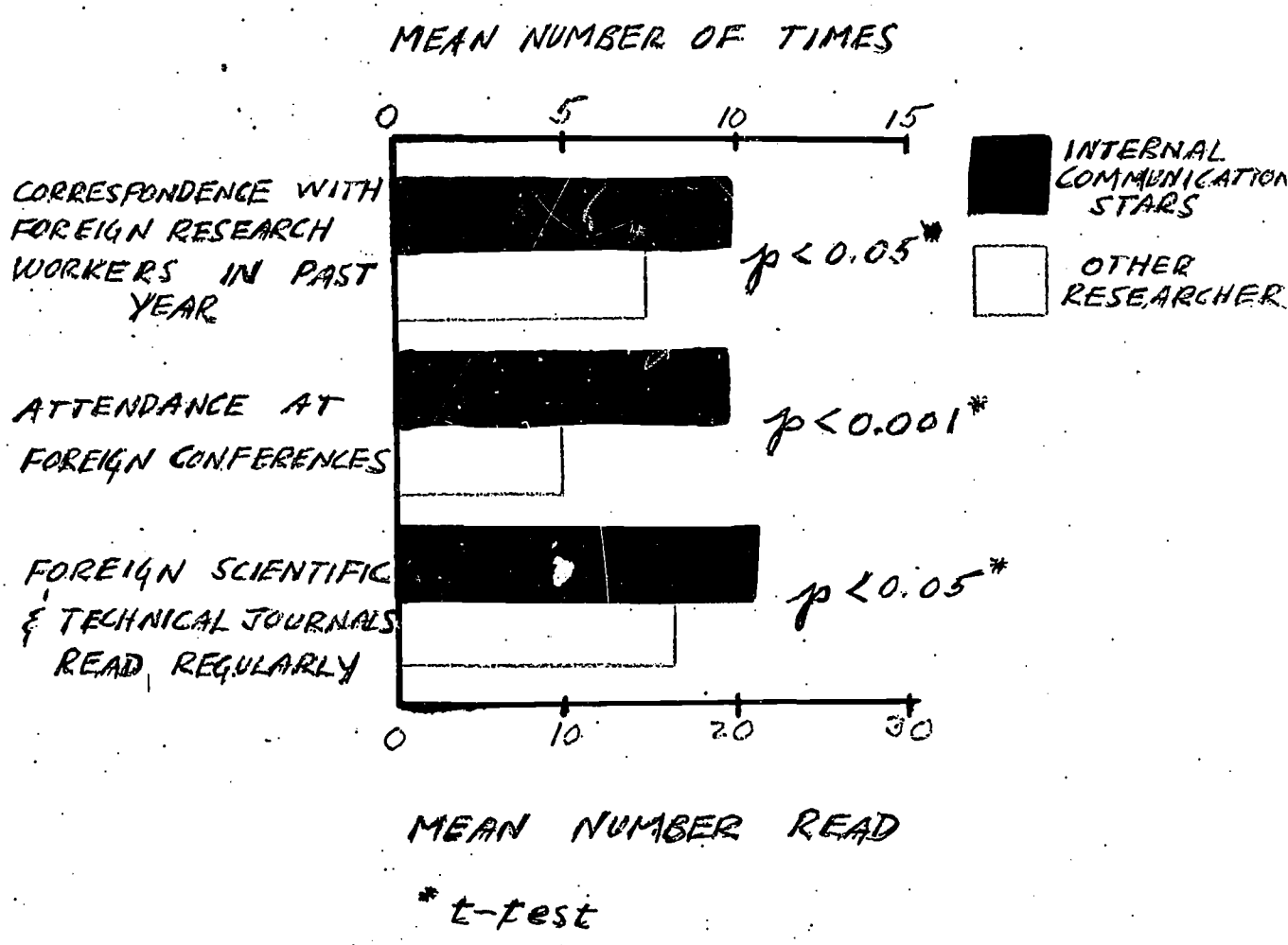


FIGURE 2. DEGREE OF FOREIGN COMMUNICATION BY INTERNAL COMMUNICATION STARS

he has instead an entire network. Information which enters the organization through one of the members of the network (a gatekeeper) is transmitted quite readily to other members of the network as a result of their high level of interaction, and it is eventually disseminated to the rest of the laboratory. This final step in the process is possible because nearly everyone in the organization is in direct and frequent contact with one or more of the gatekeepers.

In An Foras Taluntais, there are 26 scientists whose communication activities fit the operational definition for a gatekeeper (16). All but four of the 26 are members of a single or "strong component" (17) subset of the total network in which all members are mutually reachable. This group represents a very highly connected portion of the total network, whose members are in close and frequent contact with one another. (The strong component is contained within the dashed line in Figure 3.) But even the four gatekeepers who are not members of the strong component are not very far removed from it. For this reason, it can be argued that all 26 gatekeepers have developed for themselves a fairly cohesive network. The existence of the network is still more impressive when one considers the barriers to its formation. An Foras Taluntais is divided into six divisions, and the scientific activities of these six divisions are conducted at seven major locations spread over a large geographic area within the country; the distances between centers range from 15 to more than 150 miles. The gatekeeper network extends over all of the centers, and it is clear that organizational and geographic dispersion are not insurmountable barriers to communication among gatekeepers.

The gatekeeper network thus formed serves as a vital mechanism for bringing foreign science to bear upon the agricultural problems of Ireland

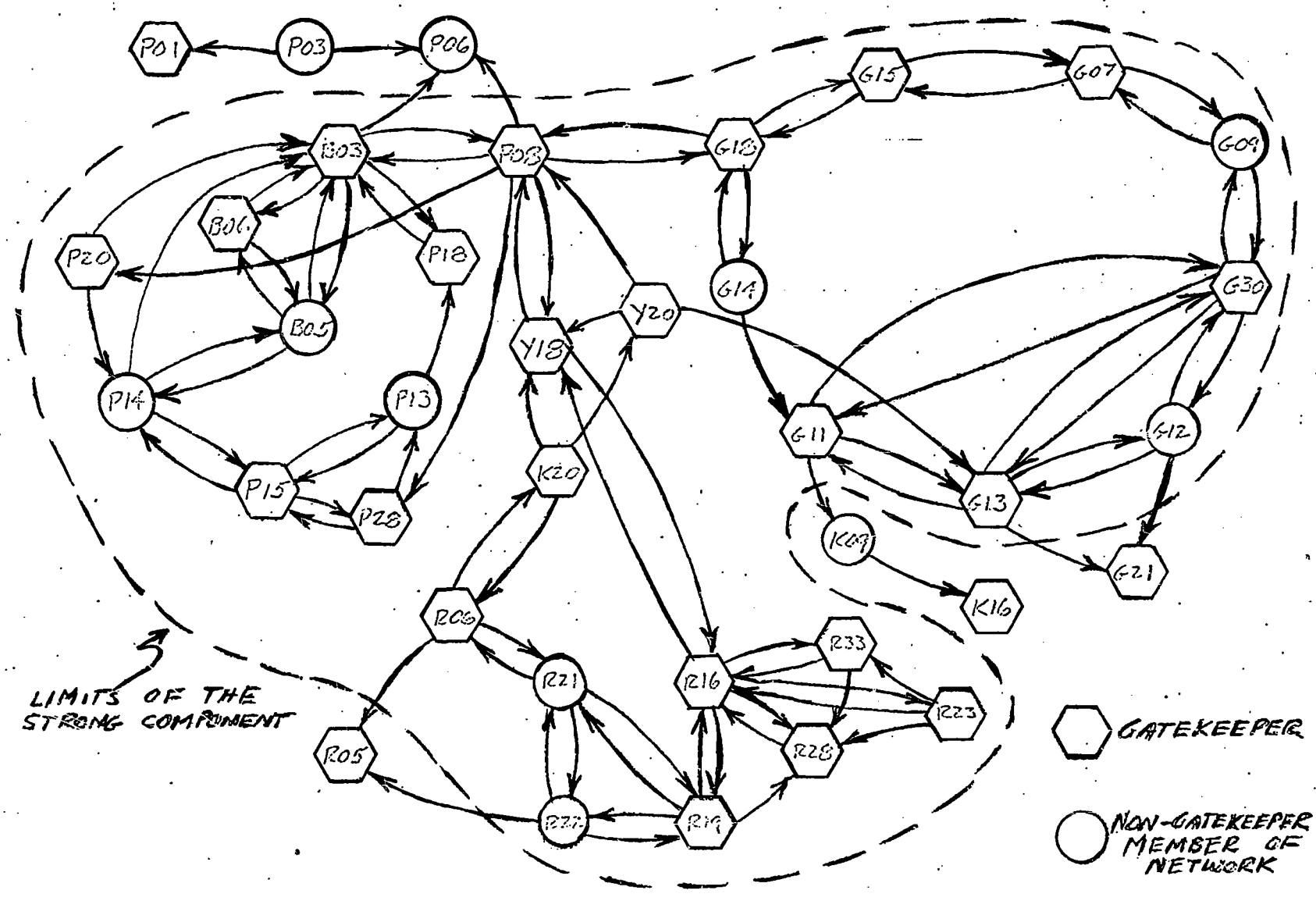


FIGURE 3. THE GATEKEEPER NETWORK

DEVELOPING INTERNATIONAL GATEKEEPERS

Given the existence of gatekeepers at an international level and their importance in coupling the country to foreign science and technology, the important problem now becomes how to develop people into this role. There are many possibilities. A scientist might develop contacts through foreign education and maintain these after returning home. If this were the case, a government desiring to stimulate the importation of foreign technical information could do so by supporting the education of its citizens in those countries with which it hoped to promote communication. On the other hand, a more direct attack upon the problem might be to encourage the employment of foreign nationals. The foreigners would presumably retain contacts in their home countries, thereby establishing themselves as potential gatekeepers for the host country.

At least the first of these propositions does not appear supportable. The people who are functioning as gatekeepers for A.F.T. were not predominantly foreign-educated (Figure 4). Proportionately, gatekeepers do not hold foreign degrees more frequently than do non-gatekeepers. Foreign education simply does not appear to be an effective strategy for creating gatekeepers (18).

Employment in research in another country is, however, quite effective. A very high proportion of the gatekeepers (89.3 percent) have either been employed by a foreign agency or firm or have visited another country to work on a sabbatical or research fellowship; it is clear that far more enduring relationships can be established during post-graduate research than during the educational process. A government wishing to establish foreign communication channels would, therefore, be well advised to support the graduates of its own universities for short periods of work abroad rather than to support its students in foreign education at undergraduate or graduate levels.

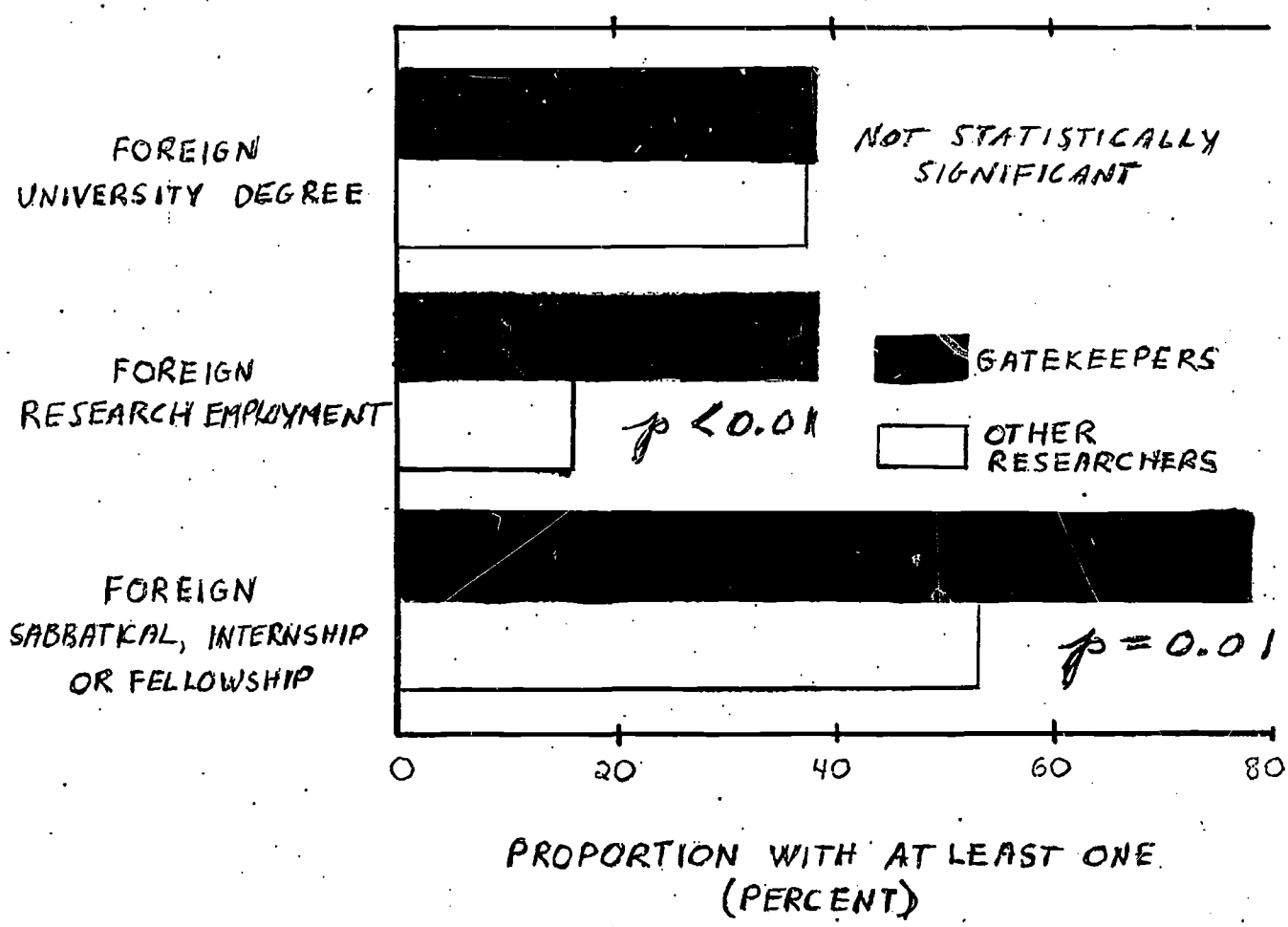


FIGURE 4. FOREIGN EXPERIENCE OF GATEKEEPERS

The effectiveness of foreign visits in promoting communication is, as expected, a decaying function of time (Figure 5A). The only surprising aspect of Figure 5A is that communication does not decay more rapidly. One would expect foreign acquaintances to die out much more rapidly unless they were periodically renewed through direct personal contact. The international scientific conference, quite naturally, provides an ideal medium for this renewal of acquaintance. In fact, this might be one of the most important functions performed by the international conference or congress (19). To test this possibility, the sample was split at the median on attendance at foreign scientific conferences. The two halves were then compared in terms of the rate at which communication with foreign colleagues decayed following a working visit (sabbatical, post-doctoral fellowship, or employment) to the colleagues' country (Figure 5B). Clearly, the international conference renews acquaintances among scientists and stimulates international communication, at least among those scientists who already know each other. In all cases, but one the mean level of foreign correspondence for high conference attenders is above that for low attenders. A Friedman Two-Way Analysis of Variance shows the two distributions of mean values to be significantly different from one another ($p < 0.001$).

THE POSITION OF FOREIGN NATIONALS

Ten scientists in the A.F.T. sample are citizens of foreign countries. While this is a small basis from which to generalize, the importance of the question of foreign nationals' effectiveness in bringing science and technology into a country is so great that we would be remiss in not considering it.

None of the gatekeepers is a foreigner. Although the ten foreign nationals all exhibit a high degree of communication with scientists outside of the country,

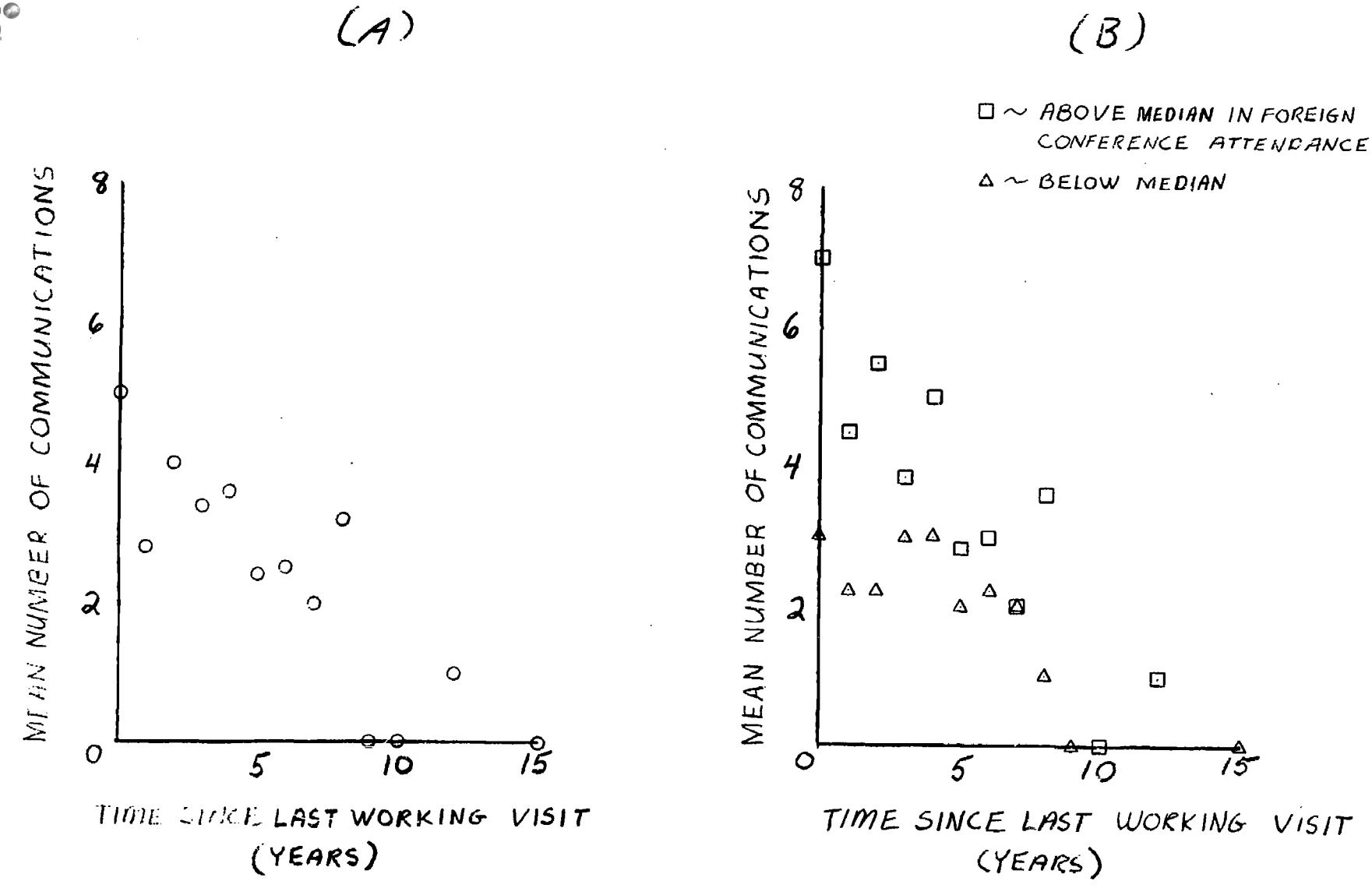


FIGURE 5. CORRESPONDENCE WITH RESEARCH WORKERS MET DURING FOREIGN EMPLOYMENT, SABBATICAL OR FELLOWSHIP AS A FUNCTION OF TIME SINCE RETURN HOME

none is an internal communication star. They are all well integrated into the domestic communication network but none to that exceptionally high degree required of a gatekeeper. The data make it clear that not all foreigners can be expected to become gatekeepers, and none can be expected to accomplish this feat overnight.

Does this mean that foreign scientists are not fully effective in the technology transfer process? Six of the ten have attached themselves in a very direct fashion to the gatekeeper network (Figure 6). They are in a position to feed any information which they obtain directly into the system with a very high probability of reaching the parties who most need it. The best compromise may be to bring foreign nationals into direct contact with those members of the organization who have the widest range of domestic contact. In this way, the number of people who have at least indirect contact with the foreigner is maximized.

The members of the gatekeeper network are, naturally, in the best position to serve as a buffer stage between the foreigner and the organization. They may also be better equipped to aid the organization in assimilating the foreigner. They have usually been exposed to cultures other than their own, and have perhaps had experience in a specific foreigner's own country. They are therefore better able to understand and communicate with their foreign colleagues and to make this expertise relevant to the problems of the country.

How can laboratories best capitalize on foreign participants in the absence or unavailability of gatekeepers? The best tactic appears to be to provide the foreigner with a close associate who, although not a gatekeeper, is integrated into the domestic network to an exceptionally high degree. This is just what happened in the case of the four foreign nationals at A.F.T. who were not connected directly to the gatekeeper network (Figure 7): They were employed at two

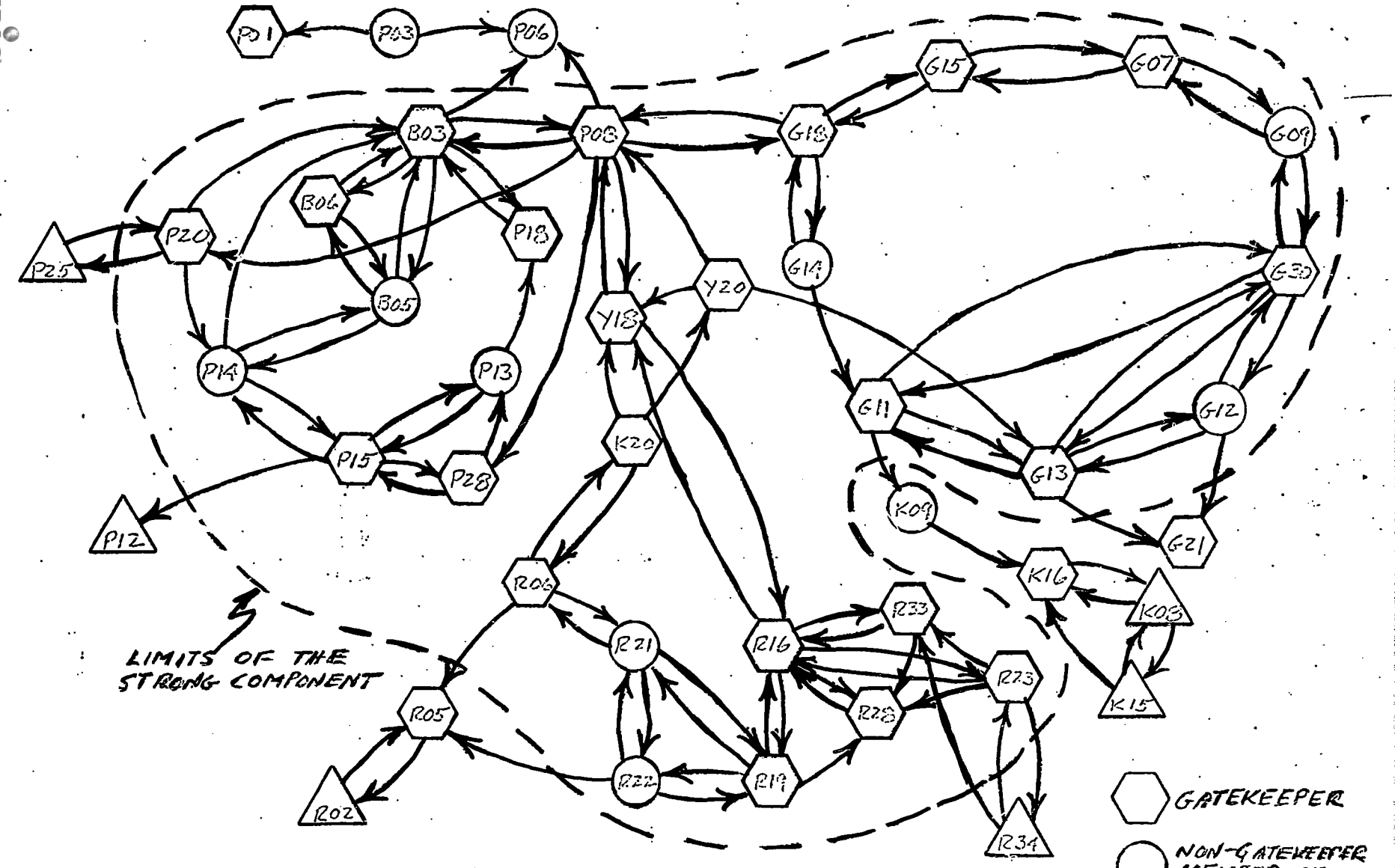
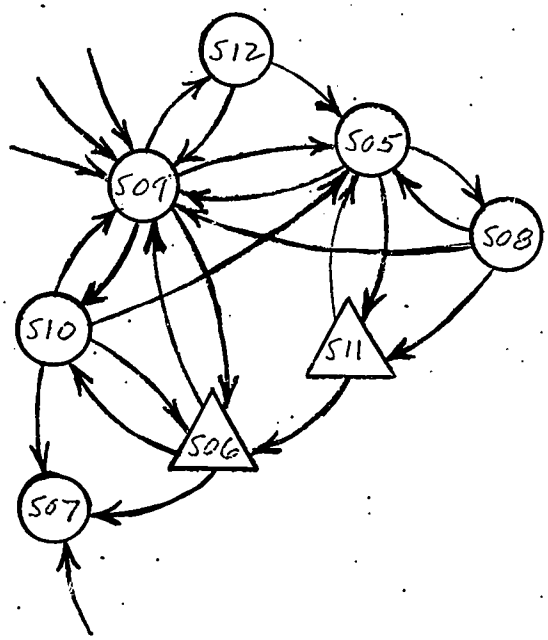
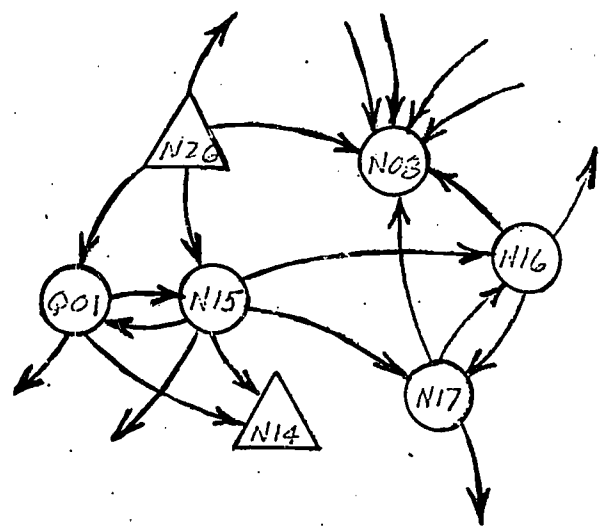


FIGURE 6. POSITION OF SIX OF TEN FOREIGN NATIONALS WITH RESPECT TO THE GATEKEEPER NETWORK.





S05, S09 & N08 ARE INTERNAL COMMUNICATION STARS.

△ FOREIGN NATIONALS

○ OTHERS

FIGURE 7. PORTIONS OF THE COMMUNICATION NETWORK SHOWING THE POSITION OF FOUR OF THE TEN FOREIGN NATIONALS WITH RESPECT TO CLIQUES FORMED AROUND INTERNAL COMMUNICATION STARS.

centers not heavily represented in that network. All four associated themselves with two cliques that had formed around three internal communication stars, thus at least assuring that their competence would be well disseminated within their respective centers.

Some Positive Aspects of the Brain Drain

Since the middle of the nineteenth century, Ireland's principal export has been Irishmen. Significant proportions of the populace of the United States, Canada, Australia and Great Britain can trace all or part of their ancestry to this island of 30 thousand square miles, which supported 8 to 10 million people in 1840, and now sustains fewer than 5 million.

In recent years, Irish universities have produced trained personnel at a rate exceeding the economy's capacity to absorb them. As a result, the level of education of the typical Irish emigrant has shifted sharply upward. Of the 170 recipients of first or higher degrees in 1967-68 from University College Dublin, who gained employment through the University's Appointments Office, 48 (28.2 percent) took jobs outside of the country (20). These highly trained emigrants represent, at least for some period of time, a valuable resource in that they can potentially be attracted back to the country. During their foreign sojourn they gain valuable experience in technologies that can be of great importance to the country. Figure 4 shows very clearly how foreign experience contributes to the development of international technological gatekeepers. In addition, there is the immeasurable benefit of applying the returning emigrant's foreign-gained skills directly to domestic problems. A selective program to attract emigrants in critical skill categories back to the country has an enormous potential for technology transfer.

Before such a program can be instituted, something should be known of the whereabouts of and skills available among recent emigrants. To this end, one question in the survey asked respondents to report the name, destination and year of departure of any scientifically trained persons, whom they knew emigrated during the previous five years. Reports were received on a total of 91 scientifically-trained emigrants. Although a sample of 91 may seem very small, out of a total population of only 1300 to 1500 research and development scientists and engineers (21), they represent a significant proportion.

More than half of the 91 emigrant scientists went to North America (Figure 8). The U.K. was the next most popular destination, with 25 percent, and the remainder scattered well around the globe with no one region attracting more than five percent So despite changes in national immegration policies, the traditional patterns of Irish emigration still appear to hold true. Furthermore, splitting the sample on the median date of departure shows no difference between the pattern followed from 1964 through 1966 and that of 1967 through 1969. This emigration pattern, then seems fairly stable, at least for the type of scientists reported on in the present survey. The sample is, naturally, heavily biased toward agricultural science. The development of a more unbiased sample must await a national survey, currently planned by the Irish National Science Council, under the direction of one of the present authors.

Emigration in this latter half of the twentieth century no longer conveys the finality that it did in former times. Not only can the emigrant change his mind quite easily and return on a permanent basis, but in the age of jet aircraft he can easily return periodically for visits and vacation as well. Respondents to the survey were asked to indicate whether or not, to their knowledge, any of the emigrants had returned for a visit and whether during the visit, they had discussed scientific matters with the respondent or any of his colleagues.

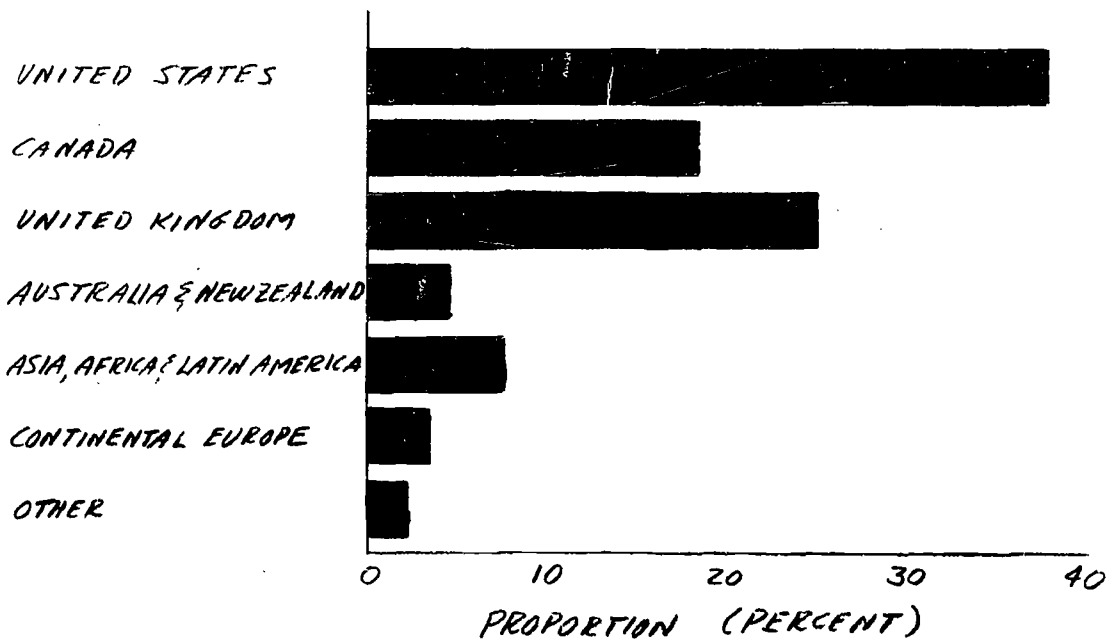


FIGURE 8. DESTINATIONS OF 91 SCIENTISTS, WHO EMIGRATED DURING THE PERIOD 1964-1969

Unfortunately the question was worded in such a way that it is impossible to determine the precise number who did return. It is possible, however, to compute from the data the minimum and maximum who could have returned. This computation shows that at least 33 percent, and possibly as many as 52 percent of the emigrants have returned for at least one visit (22). The median date of emigration for those who have returned is 1966. Since the survey was conducted in January 1970, this indicates a fairly high frequency of return visits: or at least one return within two or three years of departure. To describe a somewhat different type person, Derek Price (23) coined the term, "affluent scientific commuter"; we may find this phase very descriptive of the modern emigrant scientist. A very high proportion of the return visits have involved transatlantic travel (Table I). At least 29 percent

TABLE I

DISTRIBUTION OF COUNTRIES FROM WHICH EMIGRANTS HAVE RETURNED FOR VISITS

	proportion of those scientists who emigrated to the country, who have returned for visits	
	minimum	maximum
United Kingdom	26%	52%
United States	29	46
Canada	12	35
Australia or New Zealand	0	25
other	18	27

of those scientists who emigrated to the United States returned home for a visit. This is a proportion which is comparable to that found for the U.S. Scientifically trained 20th century emigrants are a highly mobile lot, who undoubtedly combine their high earning power, in North America, with the group discount fares

available in transatlantic travel to commute home quite frequently. Contact with these visiting scientists should be a rich source for technology transfer. In fact, the survey shows that more than half of them have discussed scientific matters with a respondent or one of his colleagues during their visits. This is the sort of practice that can and should be encouraged. Attempts should be made to retain contact with emigrant scientists, either through professional societies or through clubs in the principal countries of immigration. This will aid in future recruitment as needs develop in the home country and could allow the establishment of seminars, informal visits and consulting by emigrant scientists at key institutions in the home country. The honoraria for these functions would help to defray the cost of the vacation trip.

FOSTERING INTERNATIONAL TECHNOLOGY TRANSFER

The existence of the international technological gatekeeper as an intermediary in the technology transfer process has now been clearly demonstrated. The international gatekeepers display characteristics which are very similar to those found in American research and development laboratories. They are, on the average, technically more competent and more productive, holding Ph.D. degrees significantly more frequently than their colleagues. They regularly read a large number of technical publications.

The international gatekeeper's ability to keep abreast of foreign technological developments is an effective way for a country to import technological information. It would also appear to be a relatively inexpensive way: the cost of allowing a gatekeeper to maintain his foreign contacts through periodic travel and attendance at conferences is relatively small, when compared with the potential benefits.

The present evidence indicates that the gatekeeper develops his external contacts most effectively through active research experience in a foreign country. Much more enduring relationships seem to be established during a year of post-graduate research than are established during several years of education.

The implications of these results are unambiguous. If international transfer of technology is to be fostered, the small nation must open those channels through which information flows most effectively. It should assist able, domestically educated research personnel to do research abroad. It should encourage researchers to have foreign sabbaticals, fellowships and other forms of extended foreign technical experience. It should not, however, spend money directly on foreign education for its personnel. It should help gatekeepers to perform their role as an efficient mechanism for transfer by providing funds to maintain existing contacts through foreign travel. It should stimulate the clustering of gatekeepers into tightly connected networks so that information entering through a single gatekeeper can eventually reach any person needing it after being transmitted along the gatekeeper network. It should use care in integrating foreign scientists so that they are located at points in the domestic communication network from which their expertise can be widely disseminated by colleagues.

In addition, a reservoir of gatekeepers and potential transfer agents exists among those natives of the developing country, who are currently working abroad. Even when there is little possibility of inducing their return on a permanent basis, they can be encouraged and assisted in making brief visits to the home country and maintaining contact with scientists there. This has the twofold effect of promoting international communication among scientists who understand the country's problems and of making it more likely that the emigrant scientist will eventually return home.

The gatekeeper phenomenon is certainly not the complete answer to all of the small nation's problems in bringing new technology to its development efforts. But an understanding of the gatekeeper process coupled with a willingness to capitalize upon it will certainly be a long step in this direction, and it may be the least expensive of the several options available.

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9. J.S. Coleman, E. Katz, and H. Menzel, Medical Innovation: A Diffusion Process, New York: Bobbs Merrill, 1966.

10. P.F. Lazarsfeld, B. Berelson, and H. Gaudet, The People's Choice, New York: Duel, Sloan, and Pierce, 1948. Katz, E., "The Two-Step Flow of Communication", in W. Schramm (ed.), Mass Communication, 2nd ed., Urbana, Illinois: University of Illinois, 1960.

11. Foreign born scientists are considered specially and treated in a later part of the paper.

12. M. Woods, Research in Ireland, Dublin: Institute of Public Administration, 1969.

13. Communication stars are operationally defined as individuals with a number of branches entering their nodes (communication choices by colleagues) equal to or greater than one standard deviation above the mean number of entering nodes for the sample.

14. They regularly read a greater number of domestic journals as well.

15. T.J. Allen, Network analysis in R&D laboratories, R&D Management, 1, 1970 (in press).

16. Gatekeepers are operationally defined as communication stars who also have either engaged in correspondence with research workers in other countries or have attended foreign conferences to a degree greater than the mean for the sample.

17. F. Harary, N.Z. Norman and D. Cartwright, Structural Models, New York: Wiley, 1965.

18. That is not to say that foreign education should never be supported. There will always be fields in which the number of people who are needed is not great enough to warrant the development of a training program within the country. Foreign training will therefore be necessary in these fields. The returning student certainly brings home with him knowledge of foreign science. The only point we wish to make here is that he does not maintain contact with the foreign scientists whom he met.

19. Johns Hopkins University, Center for Research in Scientific Communication, The 1966 International Congresses of Psychology and Sociology: A Study of Information Exchange and Meeting Effectiveness. Technical Note No. 3, Baltimore, 1968.

20. Annual Report of the Appointments Office, University College, Dublin, 1968.

21. Royal Irish Academy, Register of Scientific Research Personnel, Dublin, 1968.

22. The sample may, of course, be somewhat biased toward those who returned, since respondents are more likely to remember them. Nevertheless, half the emigrants under examination left within the previous two and one-half years, making it less likely that a visit would be needed to stimulate the respondent's memory.

23. Derek J. de Solla Price, Little Science, Big Science. New York: Columbia University Press, 1963.