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THE TECHNOLOGY OF TECHNOLOGICAL INNOVATION

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This paper attempts to set forth a model of the technological innovation process, which in agriculture has commonly been referred to as research, or research and extension by adherents of the Land Grant Colleges. Further, it will attempt to apply the technological innovation process to the task of designing an organization to facilitate the process in agriculture. The purpose of the model is to provide a common place for minds to meet whether for discussing innovation in general or for designing substantive programs or administrative mechanisms aimed to produce improved technology. The paper draws heavily from the Land Grant system experience which has served its homeland well. However, its simplified terminoloby of "research and extension" has not been useful (and indeed has been dysfunctional) in technical assistance efforts in agricultural development.

Two presumptions are important to this work. One is that an indigenous capacity for innovating in agricultural technology is essential for agricultural development. This proposition has long been part of the Land Grant creed, but it has recently been tested by the thorough empirical analysis of Hayami and Ruttan (1971) and reported in their book Agricultural Development: An International Perspective, a book that is destined for landmark status in the literature of development. They further report that the agricultural innovation capacity must be in close interaction with producers and that it's programs must respond to or reflect the problems of producers. Although Japanese and U.S. agriculture are different in important ways, the indigenous innovation capacity is prominent in both histories, and the relationship with producers stands out in the profiles of both national organizations. The fact that the product turned out by these national efforts was markedly different is the really significant test of original proposition. Further, the administrative forms and the processes of evaluation of the two ayat ema were quite distinct. Supporting evidence to the Hayami Ruttan thesis is supplied by Evenson (1975-1) who concludes from empirical analysis, "Technology transfer depends heavily on indigenous research capacity. The strategy of 'waiting for the neighbor's technology to spill in' just doesn't work. Countries without an indigenous research capacity benefit very little from their neighbors." Other work has shown the relatively high rates of return to agricultural research. See Hertford, Ayer and Schuh, Griliches, Peterson, and Evenson (1975).

These researches seem to me to indicate the vital nature of the task laid out for this paper, namely to develop a conceptualization which can be used as a basis for design of an LDC innovative mechanism.

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It also places the burden of interpreting experience of relatively more developed countries so that it has meaning to the relatively less developed countries. That leads to the second presumption.

The second presumption is actually a mixture. It starts with the proposition that each of us in inescapably a prisoner of his tradition, culture, and experience, and that any effort to escape will be frustrated. The best "defense" against the cultural bias is to understand as thoroughly as possible the nature of the imprisoning forces. All of us in the U.S. are prisoners of the Land Grant experience. We have not achieved adequate success in the interpretation of this experience in ways that have meaning to the relatively less developed countries. It is my own hypothesis that this lack of success is due less to the cultural specificity of the experience than it is to the inadequate understanding of the phenomenon. We will return to this point later. It is also part of this presumption that the organizational and program administrative experience is one of the resources that the relatively more developed countries have in their efforts to assist the lesser developed countries. The MDCs have money. They also have a vast technical expertise that can be helpful, but these two do not, in my judgment, complete the kit of tools available or the kit needed. The task of agricultural development is so formidable that we need all of the tools we can get. Fortunately there is now emerging a modest research output on the organizational-administrative experience, and this research is covering experience other than our own. It is a great pleasure to have some data to resort to rather than having to rely so heavily on intuition, faith, and a modest conceptual ability, as we have had to do for so long in discussing agricultural development organization and management.

The Model

Inputs for this model have come from many sources: experience, observation, attempts to conceptualize observable phenomena, experience in the private R and D sector, and the small but highly useful body of literature on research. One purpose of this presentation is to confront the model with as wide a range of observation, experience, and wisdom as is feasible to see how well it serves and to modify it to serve better, if indeed such a model has any usefulness. This presentation is part of the crude methodology of the technology of technological innovation, the technology being that needed to facilitate the technology innovation process.

My thesis is that the Technology Innovation Process is a natural one, as far as any human or social process can be described as natural. The whole course of civilization is a course of innovation. Only quite recently has man devised administrative organization for the express

purpose of facilitating the process. As long as the process is natural, there is no need to understand it. As we attempt to organize it, understanding becomes important. It is particularly important in the present day because so many entities are working in the process, and many of them on a worldwide scope.

The model identifies eight components, including the two static states at the opposite ends of the process. Of course, these states are never static, but it seems useful in the conceptualization to move from equilibrium to equilibrium. (See Diagram, "The Technological Innovation Process")

This model connects human need with human knowledge. It doesn't show that we have needs that can't be solved from our stock of knowledge, such as cure for the common cold, and we undoubtedly have much in the stock of knowledge for which we have no need. It is in the middle ground, where either needs can be connected with knowledge or superior knowledge discovers a need, that we work. The components are laid out here in what seems to be a simple natural chronological order.

Stock of Knowledge must be regarded at the entire stock of whatever is known and not restricted to something that can be severely defined as knowledge. All of the old and current technologies are part of this stock, including folk wisdom and tradition reflected in current and past producer practice. This stock of knowledge is steadily being expanded by ordinary human experience resulting from a range of activities variously motivated. Its important to recognize the broad scope of knowledge, since *per se* one piece of knowledge is equal in value to any other piece.

Research must be thought of as systematic and organized activity carried out for the specific purpose of adding to the stock of knowledge. Research must be evaluated on its effectiveness at adding to the stock of knowledge, not the quality or relevance of the knowledge. Addition to the stock of knowledge may be motivated by nothing more than curiosity, or it may be motivated by the need to supply a specific bit of missing knowledge that in turn would have great utility in serving some instrumental purpose. The central characteristic of research, for our purpose, is that it abstracts, i.e. takes a phenomenon out of context for analysis and produces pure or abstract knowledge which is transmitted through a process of symbolic communication -- the written paper or the oral speech. Utility is of no import in evaluating research activity. Efficacy in the production of the knowledge is the principle criterion of evaluation. Utility of the new knowledge may well be important criterion for the selection of a research but not for research.

Research operates in the field of science. This model gives research (science) only one meaning, the one we normally associate with the concept basic research.

Technology development aims to select items from the stock of knowledge and to synthesize these items into a product instrumental in satisfying a human want or need. Thus we see the meaningful distinction between Research and Development. Research abstracts. Technology development synthesizes. Technology development produces something -- a commodity or a specific system or practice. It doesn't require knowledge or understanding on the part of the user. He simply needs to know how to use the commodity. Few motorists understand the internal combustion engine. Utility becomes an immediate and prime criterion for evaluating technology development efforts, although it, too, adds to the body of knowledge. However, the addition to the knowledge stock is a by-product. The principle motivation is a useful product.

Some writing on this subject provides a basis for dividing the technology development function into two parts. One part could be called the "technology design" or "technological architecture," in which it is determined what the technological development process is aiming for, and the other the "technology search," in which the stock of knowledge is literally searched for the components needed to build the technology designed in the previous function. This terminology has been developed by Evenson (1975-2) in Airlie House paper, "Cycles in Research Productivity and International Diffusion Patterns in Sugarcane, Wheat and Rice." It provides an explanation for the development of IR-8, in which according to the legend, the ideal rice plant (or variety) was literally designed in an office, and the stock of knowledge about available germ plasm was searched to find the components for the new technology. The division of technology development into two functions is also suggested by Wittnebert (1975) who used the term "engineering function" largely the way that Evenson uses the term "technology search." Wittnebert was writing of private U.S. industrial R and D and indicating that technology development not only has recourse to research but can use what is already known. Mobilizing the relevant existing knowledge he calls the "engineering function."

Drawing this sharp distinction between Research and Development in the field of agriculture has implications for organization and management of the innovative process as well as methodology. To this we shall return later.

Testing is that function which subjects a new technology to the range of production conditions. Many may prefer not to separate it from technology development. Some tests of the technology will have been anticipated. Yet there is logic for distinguishing the functions, and practice supports the distinction. For reasons of economy in the development function, it will be done within a relatively narrow range of conditions, and, given some of the demands of development, it may be done under somewhat protected conditions. In private industrial R and D programs, the pilot plant phase is recognized as a discrete step beyond the technological development phase. The range of conditions constituting the test involve ecological conditions as well as economic and social or political conditions.

Adaptation is that function by which a technology proved for one range of production conditions is modified appropriately to fit other sets or ranges. It may be regarded as an alternative outcome of the technology development function. Certainly if the modifications are great enough, a new technology is being developed. One may regard adaptation as a further step in a sequential process, or as a loop back over the latter stages of developing and testing. However, the adaptation phase or component of the process cannot be easily dispensed with, because it marks a line between the production of a new technology and the distribution of that technology.

The three technological functions -- development, testing, adaptation -- have been lumped in categories often regarded as "applied research" or "adaptive research". In agriculture the fields of science and technology have never been adequately distinguished, and as a result the terminology has not facilitated precise communication.

Integration is a complex of functions which integrates the new technology into current production systems and practices of the industry. It initiates certain components of the diffusion of function. The nature of the integration function will vary widely, being largely a function of the new technology. It may involve a simple transfer of information if the new technology be substituted for an existing technology or be added on to the current system of technologies. Many times it is much more complex. Integrating the technology of artificial insemination and of hybrid seed corn into the agricultural industry required the organization of new industries. The integrating function has been recognized in the "package of practices" concept. Integrating the new technology will often involve the sources of supply of other services and inputs.

This function in the process requires an expertise in the technology and also a knowledge of the production processes in the industry. It requires a communications capability, and often an organizational or entrepreneurial expertise. This function is to do what has to be done.

This function is closely associated with the Extension Specialists's role in the U.S. L.G.C. experience.

Diffusion delivers information of the new technology to the producers and instructs them on its use or delivers the commodity that embodies the technology, or both. This is a mass process in agriculture given the small-firm nature of the agricultural industry. This is largely a communications process in some cases. However, in others the new technology can be so well embodied in a commodity that the diffusion process consists of getting the technology integrated into farm inputs. In this case much of what is necessary for diffusion has to be addressed in the integration function.

Practice represents the end state at which the new technology can be regarded as "common practice." Conceptually it can be thought of as an equilibrium, but if a de facto equilibrium is achieved, agricultural development has not been effectively initiated. Moving from one static level to a higher static level is not development. Development requires an incline. It doesn't have to be steep, but it does have to be persistent.

Relationship of the Functions

To review a bit, up to here we have tried to discover a "natural" process that for centuries worked its way out with no attempts from the body politic to facilitate it. The technology innovation process has been treated as a chronogical sequence of events. It seems too simple and obviously more simple than we find it in practice. Yet it is probably accurate to say that the shared state of the art (i.e. the conventional wisdom) in technological innovation organization and management is perhaps even more simple. The U.S. L.G.C. dichotomy of "research and extension" is still the prevailing terminology used to describe the process, modified but slightly, with such variations as "outreach," "applied research," and "adaptive research." Use of such terms reflects frustration with the current simplistic state of the art, but doesn't help much in solving our problem.

If we study the technological innovation process, we find it is reductive through technology development and testing and expansive from there on. (See Technological Innovative Process -- 2). Through the development of the new technology the process eliminates alternatives and produces a specific, refined product. From there on it's diffused to thousands of producers. This hour-glass configuration provides a convenient point of division into the two parts of the dichotomy, research and extension. Not only does it divide them, it also relates them in time and function.

If, however, we look at what actually happens in our own system, the two parts fit together in a way that destroys the simple chronology and division. (See "Relationship of Functions in Technology Innovation Process"). Now the dichotomy is not nearly so neat. The integration function is initiated much earlier than the chronology suggests. It may be thought of as the "interaction-with-producer" function, identified as essential in the Hayami-Ruttan work, or functional or program linkage in the Institution Building terminology, rather than the "specialist function," a terminology that followed a rather arbitrary administrative form in the U.S. L.G.C. experience.

The two technology innovative organizations we know most about, those of Japan and the U.S., tended to address the right hand side of the model well before they did the left side. This in itself shakes up the simple chronology. In Japan as reported by Hayami and Akino (1975) the organization started with the diffusion function as the best farmers were organized to instruct other producers. After failure of attempts to import Anglo-American technology, the Japanese Government in 1885 organized the Itinerant Instructor System designed to diffuse the best seed varieties used by Japanese farmers and the most productive cultural practices. Agricultural graduates and veteran farmers were employed as the itinerant instructors. Concurrent with this activity Japan organized the Experimental Farm for Staple Cereals and Vegetables, which in 1893 was organized into the National Agricultural Experiment Station. Hayami and Akino characterize the early so-called research efforts as a simple

testing of alternative technologies, not research at all, not even technology development. The technologies had been developed by the natural process. Presumably tthe alternative technologies tested were those of the producers. This experience constitutes evidence that the chronology does not apply and further indicates the strong linkage with the producer.

While the U.S. experience took a different form, it probably addressed the same substance and it provides evidence of much the same order of development. The experiment station apparently came first, as a result of the Hatch Act about 1887; but the so-called extension function was well established within the decade, via the Farmer Institute. By 1909, the word "extension" was in common usage, and the experiment station directors' association had a standing committee on extension. In the early days of the experiment stations there was simply no separation of functions between "research" and "extension." Further, the farmer pressure on the stations was so great, and the experiment stations were so dependent on farmer support, that the right end of the model was not questioned in the U.S. experience. In fact under the twin pressures from farmers and from college presidents for experiment station workers to teach, the early workers had a difficult time getting to do much research in the basic or scientific sense. It should be noted here that the very term "experiment station" connotes technology development rather than research.

The lack of a division of functions between research and extension caused considerable anguish in some circles. The Office of Experiment Stations in the USDA felt that federal funds appropriated for research were actually being used for purposes not intended, namely publications and dissemination. Experiment station directors with their keen political eye (that has become traditional with professional progeny) had no compunction about using the funds for the non-intended purposes. Their faith in their clientele was well founded. Even though today's research can uncover no appreciable impact of the experiment stations on agricultural productivity during that period, farmers were supporting their experiment stations, and several states were making their own appropriations to the stations. Directors were not prone to endanger this support.

USDA was persistent, however, and in 1909, A. C. True, Director of the Office of Experiment Stations issued instructions that beginning in July all charges for extension and printing were to be eliminated from the Hatch fund accounts. In the same message he stated his great appreciation of extension work and pledged his office "to do anything in its power to aid in securing funds with which to thoroughly organize and develop extension work." (Knoblauch et al, 1962). He was probably sincere, since later in his career he was to head the extension work in the USDA.

It is interesting to speculate that this forcing of extension from Hatch fund accounts may have been a tactic to get more funds from the Congress for the experiment stations. This end was accomplished. In 1914 the Congress appropriated additional funds specifically for Extension. Whatever the motivation, this action resulted in an administrative cleavage between research and extension, strengthened by federal appropriations,

that is much more apparent than real in the way the U.S. experiment station actually operates. We have no trouble distinguishing the function of research, as the model defines it, from the county agent system. In other words, the two ends are clearly distinct. But in the middle, involving the functions of technology development through integration, even to this day, research and extension can hardly be distinguished. Perhaps the most important supporting evidence of that is the location of the Extension Specialist in most systems and the popularity of the joint research and extension appointment.

One with my own bias regarding the integrity of the innovative process as a single process can claim that it actually took an administrative decree and an Act of Congress to force the cleavage into research and extension, and even at that the cleavage only went so deep as the administrative form. The genius of U.S. public administration was able to graft over the cleavage in form to protect the integrity of the function. No harm was done as long as we were concerned only with domestic activities.

However, this cleavage has made (and still makes) much more difficult the task of interpreting our development experience into terms having meaning to other countries, especially the LDCs. Casual observers, and that category includes many L.G.C. workers, saw and still see two functions, and the tendency is strong to see them as the two ends of the process -- because that's what our terminology leads us to -- those two and thus away from the center four functions. We have overwhelming evidence of these two misconceptions in the L.G. experience in overseas technical assistance, from which we still suffer. The old Point IV effort was largely staffed by former county agents, and was a great exercise in diffusion based on the assumption that the U.S. technology was developed and ready to diffuse, a vastly oversimplified concept of extension, which actually missed the essence of extension. (See McDermott, 1971). This is hindsight, and is aimed to be analytical rather than critical. It is presented as evidence of the need to maintain the integrity of the innovative process and not to splinter it off to retail in pieces. Following Point IV in which the Universities were not involved, came a period in which the universities played the key role, the institution building period. Again we errored in conceptualization. The right end of the model didn't work, so we shifted to the left end of the model and concentrated on research with some splash over into technology development, but still no recognition of the dynamics of the innovation process. In only rare cases were the center functions in the model attended and then with little vigor. Even in those efforts in which the extension function was attended, the field component of extension, i.e. the county agent structure, was likely to be the focus rather than the center component of extension, i.e. the specialist. It is interesting to speculate on the outcome of these efforts had they been allowed to continue. The Point IV program, which by law was prohibited from research, in some cases actually moved into testing and some sort of experimentation under the guise of field demonstrations. Would it have evolved in some countries at least into an organization that served the entire process over time? And would the institution building efforts, which finally

discovered the importance of the functional linkage have moved far enough in the other direction? We'll never know. We do know, however, that in the U.S. and Japanese experience a rather long period of evolution was required to complete the system. We also know that in dealing with systems, no matter where we enter a system we will eventually be led through the entire system. Perhaps there is some truth in the old saw that in institution building projects one never fails, although it sometimes takes a very long time to succeed.

From this discussion it is possible to hypothesize (1) that the heart of the heart of the innovative process is constituted by the central four functions (technology development, testing, adaptation, and integration) and (2) that these processes are so dependent on each other that they need to be located inside the same administrative framework.

Interaction Among Functions

If we treat the technology innovation process as a system, we see that literally each piece is related to every other piece and that communication among the components flows in both directions at every interface. (See Interaction Among Functions in Technology Innovation Process). Initiation of technological innovation can begin anywhere in the system. The user can transmit a message on a need or problem. It may be satisfied or solved by any part of the system. If the technology exists, the diffusion function can simply provide it. If the diffusion function cannot, it can transmit the message back through the system. In some cases, new knowledge may have to be added. The process can start with the integration function in matching a problem of the producer with a technological opportunity. The relating of problem with possibility may be the action that initiates the process. The technological expertise may recognize a technological opportunity and initiate the process. The dynamics of the process are not well understood, either in nature in power, or in the deliberate organization to realize them.

The dynamics are receiving attention. Wittnebert (1975) discusses the importance of the market and introduces the "Innovational Grid," a management concept that pairs off technological product feasibilities with market feasibility. He recognizes the integration of these two functions in early days of smallness in corporate organization (as they were in early L.G.C. days), their having been separated as organizations become complex, and their now being reunited by bureaucratic means by the man at the top of the grid, the product manager. It is interesting to contemplate the similarity between the product manager in business and the extension specialist in the L.G.C. mechanism. In the relationship between R and D, Wittnebert recognizes that Development is dominant with research and the engineering function serving the Development function. This may be a key point in organization and management to exploit the dynamics of the process. Technology development may well be the function of the total process that can most logically generate the power both for more research and for more production innovation. Wittnebert also recognizes

the fact that innovation can be initiated by various actors in the mechanism. He calls particular attention to two -- the market which recognizes a need which would result in a need-activated innovation, and the researcher or technologist who recognizes a possibility which would result in a means-activated innovation. He contributes the thought that need-activated innovation will produce more evolutionary consequences (result in more incremental improvements) and that means-activated innovation will produce relatively more revolutionary consequences (result in more quantum improvements.)

The market concept needs attention. Business obviously lives by the market. Public agricultural research lives just as much by the market, but the dependence is not obvious. To what extent is the market in the two cases different? The market for business tends to be consumers buying a product that only one company makes. The product is the innovation. The market for agricultural research is for innovation in techniques in the production of standard consumer products. The difference may be more apparent than real. Sometimes agricultural innovation does produce a new consumer good, such as Opaque-2 corn. And some companies produce production goods for which there is a relatively wide and mass market. Perhaps the most relevant fact about the market is that it is a mass market (or at least a multiple market), that many (or several) independent firms have to make decisions, and that they will make these decisions, each in its own self-interest.

Evenson (1975) would not disagree with Wittnebert on the possible key role of technology development. In fact, he provides a useful analysis of this function withhis concepts of "biological architect," "technology design, "technology search,: which we have equated to Wittnebert's "engineering function." However, Evenson gives attention to a different sector of the model in his discussion of the dynamics of the process. His work is particularly useful in showing the mutual roles that research and science play in technological development. Research must open new possibilities for technology development and is essential in order to maintain the productivity of the technology development, because of the exhaustion phenomenon. However, influence in opposite direction is just as important. He states, "This 'design activity' is fundamental to the implementation of science. The technology designers serve to direct and orient scientific discovery toward economic objectives ... the interaction of abstraction managed by the architect has produced most new knowledge." (Evenson, 1975-2). Even though research pushes back the knowledge frontiers, the motivation and direction for it lie in the technology development function.

While Evenson is not explicitly concerned about the market as is Wittnebert, it is clear that the technology design that resulted in IR-8 and the Mex-Pak wheats had the market in mind. Further, it is clear that once the technology was in hand, the designer had a concern with exploiting the market and participated in that function. Incidentally, Evenson classifies these breakthroughs as technology rather than science. He states, "The scientific knowledge base (for the Green Revolution) had been developed over time, but resources in LDCs were simply insufficient to the task of designing technology discovery programs to take advantage of it." Evenson worries about the technological orientation of the international centers. He writes, "One of the more significant questions that the centers will have to grapple with is the 'exhaustion of potential gains' problem ... Centers are likely to be forced to return to the functions of the more

basic and fundamental sciences in dealing with the exhaustion factor."

There is considerable evidence on the need for science and research to provide the inputs into the technology development function. We have already referred to the fact that careful evaluation can detect little impace of science and technology on U.S. agriculture until the late 1930's. The experience with the soybean at the University of Illinois could well be typical. Illinois was researching the soybean as early as 1897. By 1930 Illinois farmers were growing about 500,000 acres. By 1935 the acreage had tripled, and it doubled again by 1940. The U.S. acreage traced the same pattern but lagged the Illinois pattern by five to ten years. The cause of this is quite dramatic. In the early 1920's an old line of research which featured selection (technology search of existing knowledge) was terminated, and a new line of research featuring hybridization or crossbreeding was initiated. By 1929, the Illinois variety was released to be followed soon by Chief and Lincoln. The coincidence of events is too strong to ignore. This technology development resulting in improved varieties was based in part on pure knowledge of the gene and chromosome structure of the soybean -- which was published at about the same time, by the same person who released the new varieties. (Howell, 1973)

The evidence seems to be adequate that the four central functions need to be placed in the same organization. The two end functions are essential to the process but can be provided by linkages with other organizations.

Organization to Facilitate the Innovation Process

That technology development, testing, adaptation, and integration need to be sheltered in the same organization is useful for us to a significant extent. However, it leaves many organization questions unanswered, both with respect to the minimum requirements of a national organization that will serve these functions adequately, the ways to organize interntional R and D efforts that are most compatible with the process, and the interdependence of national and international research efforts.

We have three case histories of successful organization from which we can take direct lessons but draw some inferences -- the Japanese experience, the United States experience, and the International Center experience. All these have tied our central four functions together very closely, but beyond that they vary widely.

The Japanese and United States experience tied in the diffusion function early in their developments and eventually tied in the research function, completely integrating the process. The United States system went further and integrated the scientists training function into the process. Japan may have used its R and D machinery in some way for scientist training, but the R and D machinery was not integrated with the agricultural colleges as it was in the U.S. experience. This resulted from a conscious decision that tieing R and D into the educational function would slow down the R and D. (See Hayami and Akino - 1975). The logic may have been correct, since R and D productivity can be detected in Japanese agriculture much sooner after activity was initiated than in the U.S. experience. It may have even more weight on its side in today's LDC given the fact that the task

of organizing and managing a mechanism to perform all functions may place an unreasonable burden on LDC institutions. On the other hand, there would seem to be obvious economies in training scientists in the same operation that produces science and technology.

Organization-wise there was another significant difference between the Japanese and U.S. experience. The U.S. machinery for technological innovation grew in large part from farmer pressure. In Japan the decision to go the R and D route to increase agricultural productivity was a central government decision made apparently for the purpose of developing an energy source to power industrial development. (See Hayami and Akino 1975). The Government reacted to farmer resistance to higher taxes not by lowering taxes but by attempting to help the farmer be more productive in order to pay the tax. This success of an R and D effort which was not demanded by farmers is a significant fact in designing R and D programs in countries where farmer support is not mobilized.

In the case of the International Centers, neither the research function nor the diffusion function was included in the organization. Center impact on productivity came more quickly and with more force than occurred in either of the national cases. In a sense it would be expected. The centers drew heavily on those two national systems for personnel, for organization and administration, and for scientific knowledge. The centers have obviously been successful in establishing linkages with national diffusion systems, which is a large part of the integration function. We have no data on their linkage with scientific research systems. We know they took advantage of unused scientific knowledge, but have the functional linkages been established toward science as they have toward diffusion? The diffusion systems with which the centers are linked react rather successfully to the technology and integration efforts of the centers. Are the linkages in the other directions such that the technology design and the management of the architect can have a parallel effect on the producers of new abstract knowledge? If not, what alternatives are there for supplying relevant new knowledge for the active programs of technology development of the centers?

What are the implications for AID and for the U.S. L.G. colleges that grow out of this model and the conclusion that we have seemed to arrive at.

1. One is that AID and the L. G. C.'s face very much the same set of problems and that each has its own resources to bring to bear on the problem. AID relies to an extraordinary degree on the L. G. C.'s currently more for manpower than for conceptualization , but the needs for conceptualization and design are probably equal to those for manpower.

2. None of the three case histories above provide blueprints for building LDC capability which this paper holds is essential. The Japanese and U.S. model simply take too long. The international center model takes too many resources to be replicated in each LDC.

3. The three experiences do provide some guidelines if we are successful in drawing the correct inferences. The center experience indicates that the massive diffusion machinery (the county agent system) associated with the U.S. L.G.C. model does not have to be part of the central innovative machinery. It can be substituted for by a variety of other systems that exist in many LDCs. If this inference is correct, it relieves the designers of LDC systems of large financial and administrative burdens. It shows, however, the need to link with diffusion systems. The centers have had enough experience in linking with diffusion systems to provide considerable guidance in this area. This resource must not be overlooked.

4. Centers have also demonstrated that scientific knowledge can be brought in from outside the system (as did the Japanese and U.S. experience), but we are still faced with the question of how to structure this importation. And we do not know the impact of this importation possibility on the minimum requirements for the national innovation organization. If it is the biological architect who stimulates and guides the search of new knowledge through his technology design, how can this function be provided in a multi-system or inter-system type of organization? Can there be some sort of super system that will perform this function? The Consultative Group for the International Agricultural Centers may be one such group. Curiously, the AID is almost in a position to play a role in this area, with its own program linkages to the centers, to the U.S. L.G.C. complex, and to the LDC national research organizations.

5. On the international scene, the research project may be a very weak instrument. Certainly the current conceptualization of research and utilization is inadequate to the task of organizing the innovative effort. A more proper instrument may be the program, involving several projects in achieving adequate integration of the functions in the process. The biological architect may need the collaboration of a program architect whose responsibility would be to design the task system by which various entities could be hooked together to provide the administrative support and protection for the innovation process.

6. Looking at the national problem, we have mobilized almost no knowledge concerning the organization and management of LDC innovation capacity other than making a crude transfer of MDC management practices and philosophies. This is clearly inadequate. The central issue in solving this problem is the extent to which it is feasible for the country to rely on the international mechanism in developing its own innovation capacity. In order to resolve the issue of extent, we need to know what alternatives are feasible. The international network is a useful concept, but until it is translated into concrete operational organization it will not carry us very far.

This paper has not answered many specific questions. It set out to provide a conceptual model that would help standardize concepts and terms as the many actors try to work on the problem. It also aimed to structure the task of organization and management of the technology innovation process.

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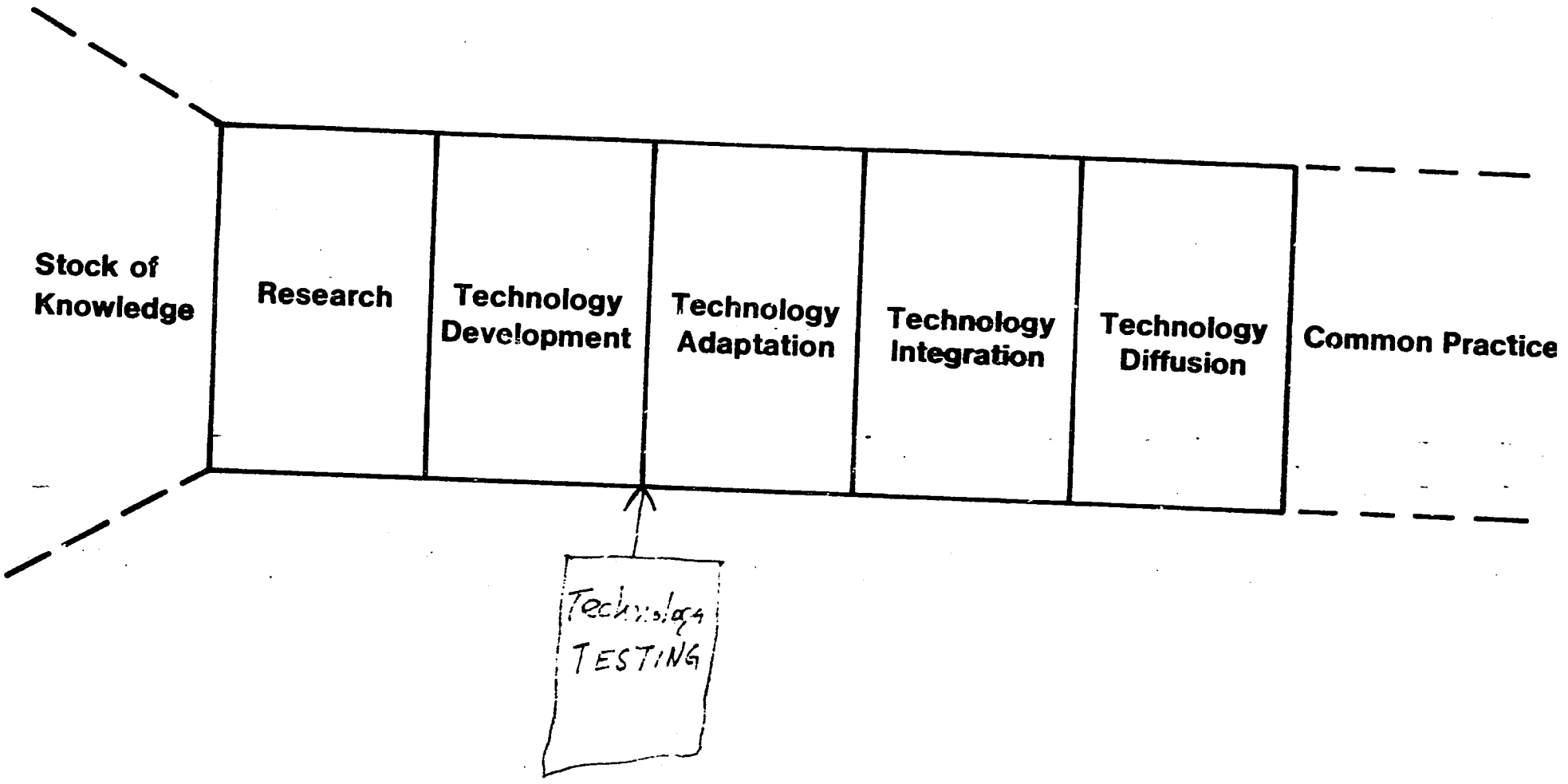
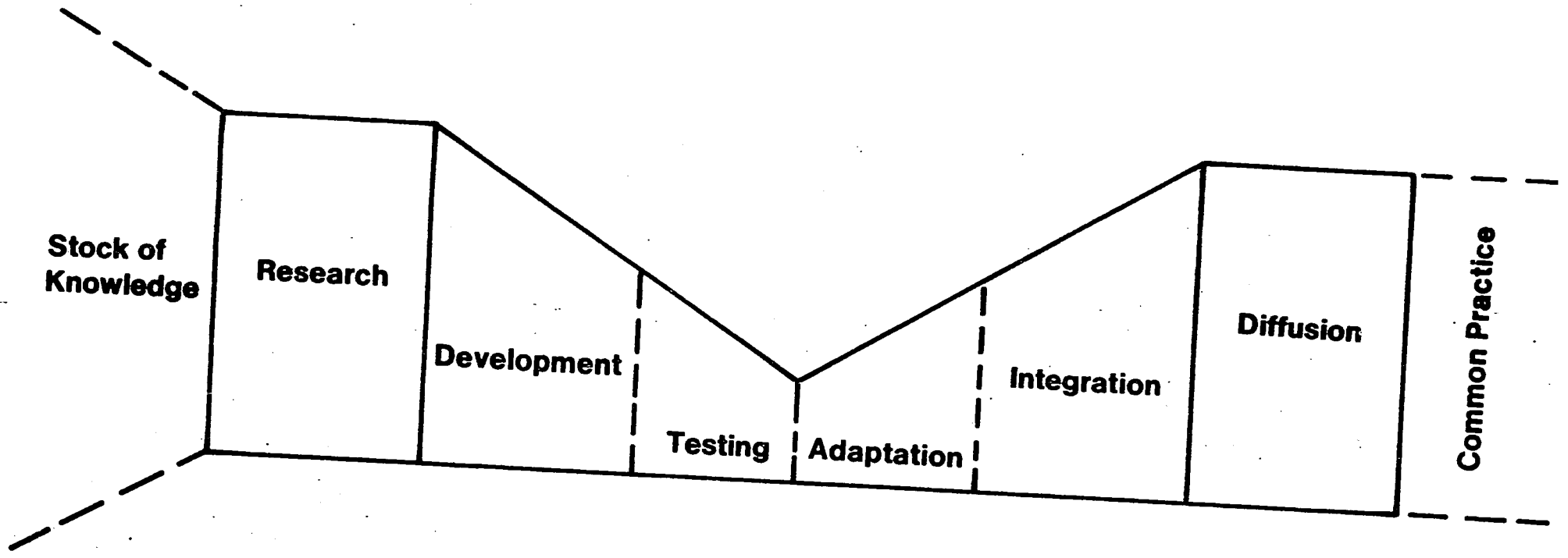
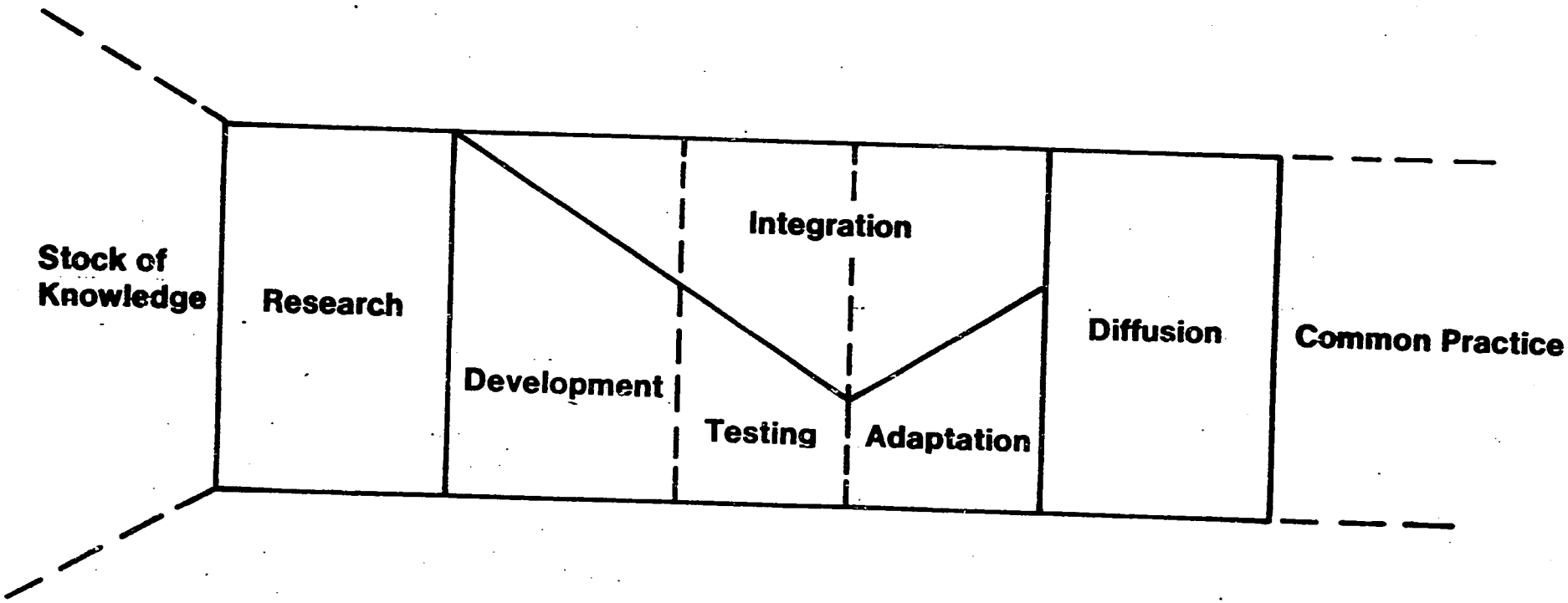
The Technological Innovative Process



Technological Innovative Process - 2



Relationship of Functions in Technological Innovative Process



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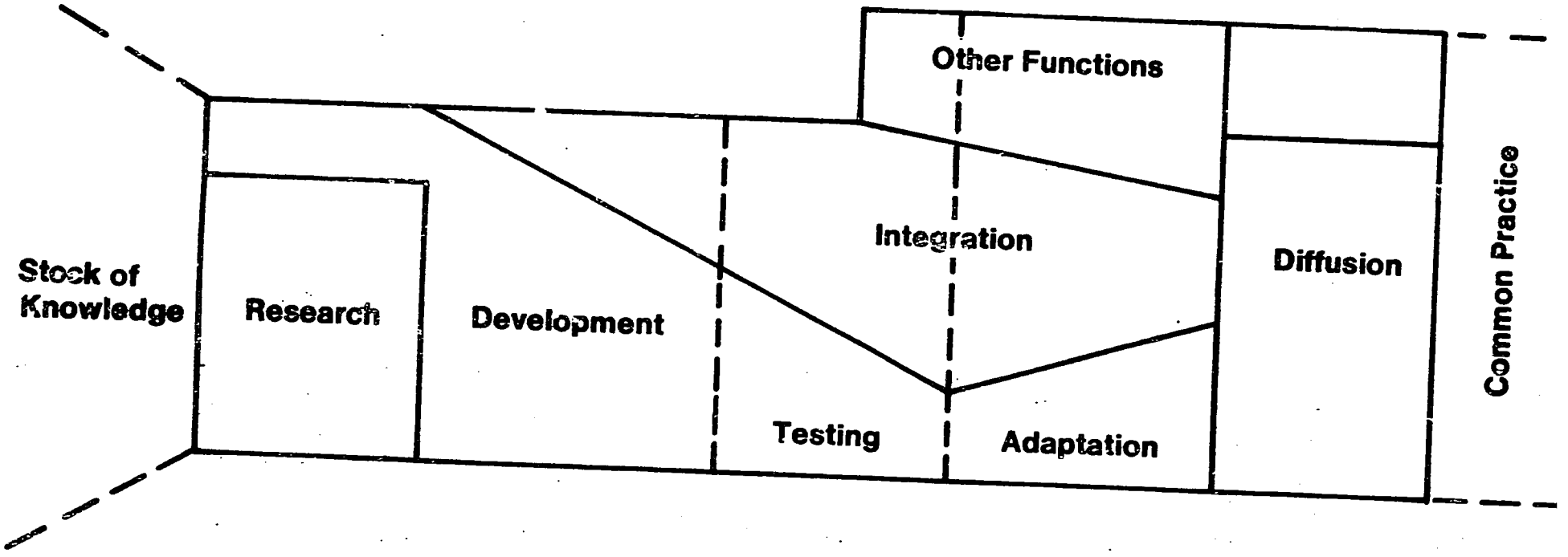
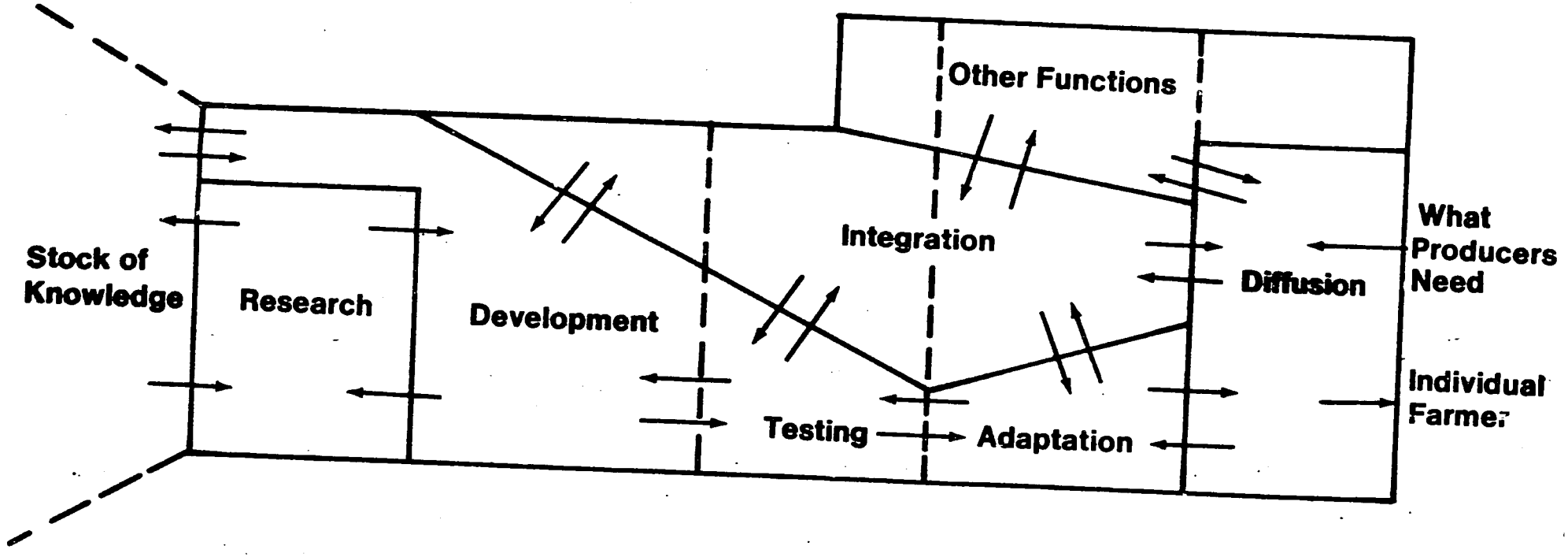


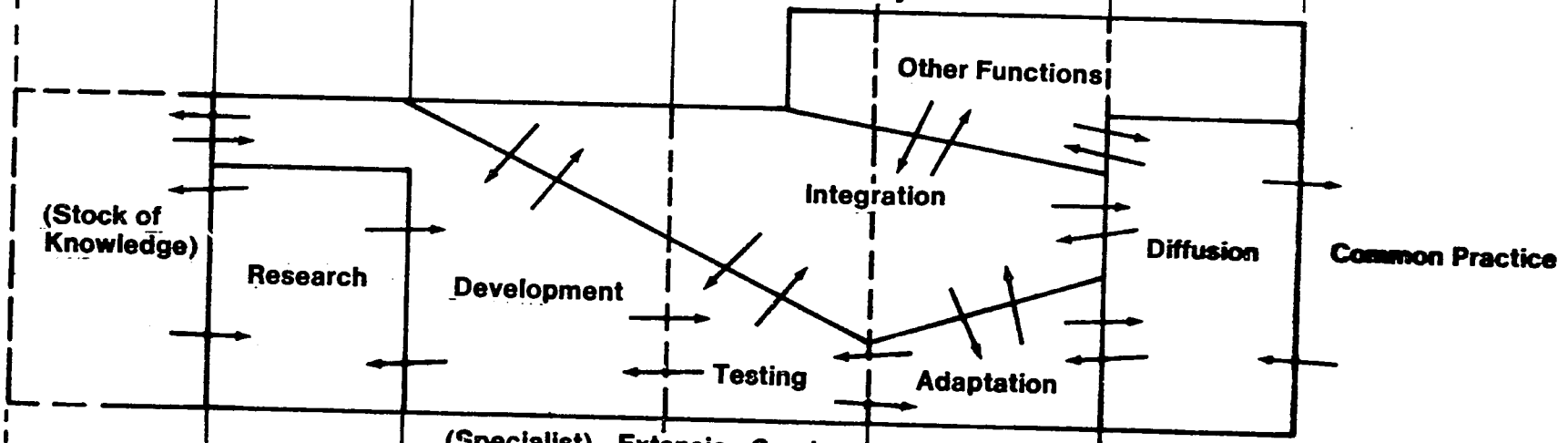
Interactions Among Functions in Technological Innovative Process



Arrows indicate transfer of one or all of message , substantive information, or service.

Description and Analysis of Functions in Technological Innovative Process

Substance ~~Function~~	Library Science	Science ~~Research~~	Technology	Technology Industry Organization and Production		Production Technology
Function	Information Management	Research	Development	Testing Integrating technology into industry	Adaptation	Informing Instructing



Organization in U.S. Ag Experience (LGC)	Experiment Station		(Specialist) Extension Service			(County Agent)
			Industry	Other Agencies		Press, Others
				Producers		
Organizational and Personnel Needs	Organization, access, with strong linkage to users	Scientific–Conceptual skills Ideally would be in organization to right, but would serve variety of entities.	Technical Scientific skills These four functions appear to be inseparable. The organization that shelters them must develop strong linkage in three directions.	Technical engineering skills		Communication skills Various field type organizations can serve