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The Relationship of Science to the North-South Dialogue

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The dialogue between the Northern and Southern hemispheres of this one Earth is concerned with the issue of human equity. It is the dialogue between those in the north who have an abundance of goods and services, with a generally improving opportunity for self-fulfillment, as contrasted with those in the south who are deficient in even rudimentary goods and services and whose opportunity for self-fulfillment is not only smaller than their brothers' in the north but is probably diminishing.

The mind-numbing plight of the poorest of the poor in this world shall not be inventoried in any detail. The absolute quality of that poverty defies the very language used to describe poverty as known in the United States. While there is valid concern with the quality of water drunk by humans in the Northern Hemisphere, it is a problem orders of magnitude removed from the grossly contaminated water available to more than one-half of the people of the Southern Hemisphere and responsible for most of the infant deaths associated with diarrhea.

Unemployment in urban centers of the Northern Hemisphere is an appropriate concern, but the increasingly urbanized population of the Southern Hemisphere has unemployment rates that approach two-thirds of some cities' population and, if anything, are increasing rather than decreasing.

With only a few outstanding exceptions, the new countries that have been created since World War II in the Southern Hemisphere have populations that are deeply disappointed with the outcome of political autonomy. Governments are overwhelmingly non-representative and authoritarian, centralized in their decision making, and militaristic in their power base. The promise of free trade in an open market bringing inevitable benefits has proved cruelly elusive. The opportunity to participate in the benefits of a technology that is ever more sophisticated and more nearly science based has evaded the developing countries as they have attempted to use it in their industrialization programs.

In the North–South dialogue, the majority of the people of the world seek a new economic era characterized by self-reliance and an equality of access to the productive resources of the world. The Northern Hemisphere, for its part, seeks to maintain the functional integrity of that system to which the Southern Hemisphere seeks access. Philanthropy that perpetuates dependency is unacceptable; and so is a set of responses that would give away established technology without preserving its source. Whether the tensions created by the terrifying difference between the "haves" and "have-nots" of this world will tolerate the constrained rate of change desired by the Northern Hemisphere is, at best, problematic and has a character of tragic drama, since the uncertainty transforms this dialogue into a discussion of the future of humanity.

THE NATURE OF SCIENCE

The much more limited question of the relationship of science to the North–South dialogue has its relevance derived in the most general terms from the fact that science is part of human experience and, insofar as known, is one of those activities that uniquely defines mankind. But the practice of modern science falls outside of the realm of common, everyday experiences. Within the body of science itself, the realms of inquiry are so segregated by the demands of specialized knowledge and technical skill that coherence can be achieved only at the highest levels of aggregation. In these terms, however, science can be understood as a quantitative description of events that recur in a regular association over time. From these associative descriptions, causal inferences are hypothesized and offered as scientific explanations. These explanations are now increasingly derived from experimental conditions but are applicable in principle to spontaneous events. The inquiries of science arise from individual curiosity. As observations and the inferences derived from them create new understanding, the opportunities for inquiry are thereby expanded so that the direction of new research is selected by the new questions revealed through the most recent increase in understanding.

As science is creative, so it is unpredictable. The content of science in its pure form contributes to human understanding of the nature of material events. This is the inherent function of science, and it needs seek no other in order to justify its efforts. But, it is simply the case that scientific understanding has more than one function in human experience—that it is, indeed, pluripotent. Like the genetic pool that characterizes mankind itself, scientific understanding can have an enormous variety of expressions in response to the selecting influences of the cultural setting and the nature of the felt needs that influence alternative actions.

In science itself, the questions that are asked are disciplinary in orgin and are responsive in the first instance to issues of relevance within a discipline. There is no necessary relationship between the elemental function of increased understanding that characterizes science and the existence of other functions outside of the scientific disciplines. The utility of the applications of scientific understanding is a result of the application of knowledge to the satisfaction of a felt need, not the result of the progress of science itself.

THE NATURE OF TECHNOLOGY

Technology may be described as the application of knowledge to meeting felt need. This definition comes perilously close to invoking the concepts of purpose and the existence of freedom in the choices made by humans. The religious concepts of predestination, the mechanistic theories of the behaviorists, and the probabilistic quality of explanations of scientific materialism all argue against the notion of either purpose or free will. Nevertheless, the variety of available expressions of the human genetic potential, coupled with the extraordinary rate of cultural evolution of the past 10,000 years, suggest that the order of certainty of predictability of choices in the human free-living state is so low that it has little utility in the everyday experience of a lifetime. It is probably true that the entire potential of this universe was fully represented at the time of the creative "big bang." Indeed, it is at the moment of the "big bang" that the arguments of human purpose come to their absolute intersection. At that point, the argument passes beyond the context of the present subject.

Nevertheless, these considerations are important since technology must be understood as highly circumstantial and responsive to the momentary conditions that surround a felt need. Therefore, it is an ephemeral expression, chosen at one moment and as only one of a multitude of possible applica tions of that moment's understanding. Because both understanding and felt need vary over time, technology varies as well. The term "appropriate technology" is redundant. It is useful, nevertheless, to emphasize that technology is not designed to be transferred from one time and one setting to another. It is only by chance that a technology in one place and time is suitable for another place and time. But, there is enough similarity in the human condition from time to time and from place to place so that there are common-felt needs that are met by common technologies.

Historically, technology drew first on everyday human experience and long antedated the development of science. Today, new technology is increasingly derived from the abstractions of science and is not only developed to meet perceived and felt needs but is also constrained to a manner that allows consumption through an economically effective demand. The relationship of a Steinmetz to the General Electric Company, a Tesla to the Westinghouse Company, a Paul Ehrlich to the Hoechst Company, and the "Bell Laboratories mode" of institutionalized interaction between science and industry exemplify the nature of modern scientific technology. The power of this modern technology is remarkable in part because of the tiny portion of the total body of science that it utilizes. As this body of scientific understanding increases and the institutional arrangements for the interaction of science and industry are maintained, there exists the potential of more satisfying technologic responses in the future than have been available thus far. But, in the Southern Hemisphere science itself is underdeveloped, and the institutional arrangements that link science to industry are frail and unreliable.

THE RELATIONSHIP OF SCIENCE TO THE NORTH-SOUTH DIALOGUE

Science becomes relevant to the North-South dialogue because it is part of the entire human experience. Science is not unusual as a human endeavor and it has an evident evolutionary advantage primarily responsive to that human-felt need called "curiosity." It becomes remarkable because it can be utilized in response to so many other human-felt needs and because it is so openly flexible in its range of possible applications that the great variety of choices it provides invokes the concept of human purpose.

Among the most important aspects of science that give it relevance to the North-South dialogue is the beginning understanding of human nature itself. The biological science of "evolution through adaptive selection," the new science of molecular genetics, the increasingly quantitative social sciences, the vast array of behavioral sciences that reach from individuality to correlation with biochemistry and physiology, and that newcomer from the science of ethology that calls itself "sociobiology" are all contributing to this beginning understanding. As North–South dialogue is undertaken, it will be important that conversations are illuminated by these insights from a scientific description of human nature. A few of them are:

Altruism is an essential component of the adaptive survival of the human species.

Mankind is a closed genetic pool, separated from all other species and existing with relatively minor variations wherever human populations are found. What is called "race" is such a minor variation on a theme.

This single genetic pool has within it a degree of variety that probably assures the uniqueness of each individual and provides many alternatives to the particular set of expressions of genetic potential today called "civilization." This potential is not a function of geography.

The culturally influenced expression of genetic potential that has characterized civilization for the last few thousand years is simply that: one short period, one single set among many possible sets of expression of human genetic potential. The capacity for variety and unutilized potential gives a rational basis for hope in the future adaptability of mankind.

In short, science is relevant to the North–South dialogue because, from the rigorous and critical perspective of scientific materialism, it restates the intuitive and religious affirmation that the brotherhood of man is real. As John Donne (*see* Hillyer, 1941:331) expressed it so many years ago, this brotherhood is unavoidable. In a very different tone, science exclaims that the bell rings for us.

THE NATURE OF THE PARTICIPATION OF SCIENCE IN THE NORTH–SOUTH DIALOGUE

Science participates in an interactive system that, through the industrialization of technology, results in the availability and consumption of wanted goods and services. It is the effectiveness of this system that characterizes the basis of the advantages of the Northern Hemisphere. This system is the means by which scientific understanding provides the feasibility of technology, and the felt needs of the consumer are the motivating initiative for the system.

Although science does not have any necessary concern with the possible utility of its understanding, it cannot be blind to the fact that this understanding has wide application outside of the field of science. Actually, the very basis of societal support of science is the perceived contribution that applications of science make to the improvement of the human condition. In recent times assertions of the intrinsic value of science and assertions of lack of responsibility of science for applied utility have partially alienated the scientific establishment from those responsible for resource allocation. Historically, this is a more accustomed state than the unusual period of 20 years after World War II when science was provided with more support than it could decently assimilate. Nevertheless, public confidence in science remains high. Despite its self-indulgent elements, science is highly valued because it can make hoped-for improvements in the human condition feasible.

The large and complex system that uses scientific understanding in the industrialization of technology and disseminates the output to meet the felt needs of the ultimate consumer suffers from the entropy of all closed systems. It is scientific understanding in its ever-enlarging magnitude that uniquely maintains the system as an open one. This contribution of science is a form of negentropy and allows the system to overcome the limitations to its growth needs and its functional integrity. These limitations that are inherent would be destructive if the system could not trap the energetic input of increased scientific understanding. Without this input of science, those forms of entropy described by Karl Marx (Marx and Engels, 1848) and repeated by the Club of Rome (Meadows et al., 1972) would probably, in fact, destroy the effectiveness of this existing system in meeting the felt needs of humans for goods and services.

From the great variety of applications that can be made from scientific understanding, it is necessary in our time that the discipline of scientific materialism be utilized to influence the choice of those alternatives of technology that will allow for the survival of the human species and the fulfillment of the human genetic potential. The Luddite view, that technologic innovation should be suppressed, is an expression of hopelessness and arrogance; hopelessness, in that variety and change are looked upon as threats; arrogance, in that the current meager expression of the fulfillment of human genetic potential is presumed to be so gratifying that it should be preserved. The Luddite view is also a futility, since, from the time of the origin of this universe to the present, and probably for whatever may constitute the future, the most reliable observation is that things change.

THE AGE OF INFORMATION

It is not clear that humans are adapted through evolution to this new problem of choice based on scientific understanding. Adaptive selection of choices, now and in the future, will have to include large bodies of information that are stored externally. Until the present generation, the data base that mankind has relied upon in selecting responses of adaptation has been predominantly outside the realm of consciousness in the stored information of DNA. A much smaller data base, made up by the conscious recall of experience of the individual, influenced the selection of alternative actions within the wide limits of genetic capability.

In this and succeeding generations, humans will have access to data relevant to the human condition in larger amounts external to the genetic pool and to common experience than will exist internally. More importantly, the access to and control of consciousness of this external information is very much less well managed than is the traditional data base. Inundation with information from the mass media is reminiscent of the rushing, fetid output of a *cloaca maxima* rather than the refined and selective management of information flow that characterizes the human consciousness. At present, redundancy and overload, along with misleading context and volumes of sheer erroneous data, characterize the ambient information flow. This, too, is a characteristic of the Northern Hemisphere. Only here has this remarkable misuse of external data been achieved. In the Southern Hemisphere, the unavailability of the technology of information transfer creates an absolute deprivation of common access to current information.

One of the very most important opportunities that presents itself in the North–South dialogue is to make the data transfer systems that must be developed in the Southern Hemisphere more responsive to the fulfillment of those felt needs that are related to the survival of the species and less to the goals of titillation and selfishness. Radios, the printed word, the use of broad-band technology, and the economies of satellite transmission have yet to be available universally in the Southern Hemisphere. Hopefully, the system of incentives and rewards that can be developed will avoid the gross environmental pollution that passes for information transfer today in the Northern Hemisphere.

SCIENCE-BASED TECHNOLOGY AS THE FOUNDATION OF INDUSTRIAL DEVELOPMENT

The utilization of scientific understanding in the development of technology that responds to a felt need is only the very beginning of the process that allows the goods and services produced by this technology to reach the ultimate consumer. This latter process has been described as the dissemination of innovation. It is a field where scientific analysis is in its infancy. In the most general terms, dissemination of innovation is the process by which novel information and technology are initiators of a behavior change that includes their utilization. The system rests at one extreme on scientific understanding and on the other extreme on rewards to the supplier from the benefited consumer. This availability of incentives and rewards to the supplier component of the system provides resources required by the body of science as well as all the other necessary components of that system. In general, the capacity of the ultimate consumer to acquire and share benefits is described as an economically effective demand. It is the transfer of value from the user to the supplier.

The cost of research and development, as well as the cost of all the other components of the system, is great indeed. Whether the system of value exchange is barter, a centrally planned economy, or some variety of the free-market system, the end user still must be able in some way to pay the whole cost of the value received in order that the system itself can be sustained.

HOW IS SCIENCE COMMERCIALIZED?

The details of the process of industrialization and commercialization of scientific understanding are only very partially understood. It would appear that the rate of return on investment in research and development has decreased in the past decade where it can be measured over this time. On the other hand, it is also obvious that the exports from the United States of greatest value are those that are derived from the handful of industries that are based on high technology derived from their own research and development.

In considering the commercialization of science it is important at the outset to understand that there is no known utility for most of scientific understanding. Furthermore, it is not possible to direct, any more than it is possible to predict, the course of scientific research. It is, therefore, impossible to describe any meaningful relationship between the volume of scientific research undertaken, the amount of incremental understanding achieved, and the quantity of new technology that flows from this effort that will be commercially viable. In short, there is no generally acceptable calculus that can quantify the obvious relationship between scientific understanding and commercially successful technology.

Most of the efforts made by small or large businesses to utilize scientific knowledge in producing a new and utilizable technology fail utterly. Files of every patent office in the world stand as mute records of this high probability of failure. For every patent filed, there is an unknown but very large number of efforts that also consumed great amounts of time and were characterized by brilliant imaginings that proved to be so nearly useless that even filing a patent application was not considered justified. Since those outside of the system that actually develops technologies see only the successes, it is sometimes hard to provide an appreciation of the background of common failures against which these uncommon successes are contrasted.

The cost of demonstrating technologic feasibility from scientific understanding is great, but nevertheless a very small part of the total cost of providing general availability of the goods and services derived from that technology. The support of all of science that leads to and the support of all of the efforts that prove the feasibility of a technology probably represent considerably less than 10% of the cost of making that technology generally available. Moving the technology from laboratory scale to pilot plant and then to production scale is the beginning of the incremental expenditure. The provision of fixed-capital expenditures for building and equipment is a new order of expenditure. The demands for working capital to fill the pipeline from raw materials to finished inventories and to provide for receivables depends on the degree of utilization for its actual size but may exceed all prior expenditures. The ongoing cost of marketing and distribution so that the goods and services are conveniently available to the final consumer is itself a major expenditure. More recently, governmental regulations have been the most rapidly growing cost segment of this entire process.

The operation of science- and technology-based industrial systems shall not be elaborated. What is important to understand in the context of the North–South dialogue is that the system uniquely exists in the developed countries, and it is that system to which the less-developed world wishes full and equal access.

In the United States there are five scientists and engineers in industry for every two in academia and government combined. It is the presence of these scientists and engineers in industry that makes it possible for scientific knowledge to be translated into a utilizable technology. This pattern in the United States is similar to the one in Germany and in Japan. In less-developed countries, however, the numbers of scientists and engineers in the private sector are very nearly negligible. Indeed, the relationship of science and technology to the private sector is so weak in most less-developed countries that it constitutes one of the major impediments to the transfer of current technology, much less the development of self-reliance in technology.

The present system in the developed countries requires that a successful group of currently marketed products be available to support ongoing research and development. Furthermore, a steady flow of new products is necessary in order to maintain the system in being. Research and development is therefore highly concentrated in a very few industries in the United States, as in all developed countries. It is not correct to imagine that all American industries are busily engaged in scientific research. Long-term strategic research and development analogous to the basic research of science is decreasing in the United States' industrial sector. Nevertheless, the absolute amount of basic research carried on within industrial laboratories is significant. In dollar terms, it approximates the entire budget of the National Science Foundation. Therefore, when it is suggested that basic research in industry is decreasing, it is a major portion of the national capacity for basic research that is at risk.

In the industrial sector in the United States, the decreasing productivity and decreasing capital formation that characterize industrial trends threaten the foundations of support for research. The managerial decision to allocate funds for research and development in industry has the characteristics of a capital investment. That is to say, it is a current investment for returns that will be realized years later. In the case of the pharmaceutical industry, that is frequently 10 to 20 years later. In order to make such a decision, the rate of return on funds invested in research and development needs to be greater than the cost of acquiring those funds. Obviously, inflation and rising interest rates make this condition more and more difficult to meet. Furthermore, the rate of return on research investment must be enough to pay back the expenditure in a defined time so that when the life span of one product is finished funds are available for investment in a new product. The eroding margins of profit of industry in the United States, and the increasing use of debt by American business, is placing great pressures on the decisions of management to limit allocations to research and development.

These few remarks about the nature of industrialized scientific applications are made not so much to describe the process with any degree of completeness, but to point out that it is by no means assured of continuing success. It is, in fact, a very fragile arrangement that is already showing threatening signs of dysfunction. The support of the vitality of the research-based industries of the United States has now been elevated to the level of national policy, and in the President's Office of Science and Technology there is a large ongoing study intended to illuminate policy options that can improve the likelihood of the survival of what has been a most powerful and successful enterprise.

SURROGATES FOR THE MARKET FOR SCIENCE-BASED TECHNOLOGY

Because of the very long time it takes for scientists to be trained and the even longer time that it takes for the institutions that support the practice of science to evolve, it is a certainty that for a long time—at least a few decades—the United States, along with the other developed countries, will continue as the major sources of new scientific understanding. Because of the complexity and uncertainties of the system of industrialization of scientifically based technology, the practice of science in its application to technology will also remain predominantly in the United States and in the developed countries for a long time to come. What is different, in an almost revolutionary sense, is that the potential markets described by the unmet needs of the Southern Hemisphere are essential to the continuing vitality of the science-based industry of the Northern Hemisphere.

Long term, the less-developed countries seek to iterate the development of the system that is now in being in the developed countries. Furthermore, they wish to participate immediately on equal terms of access to the existing system in order to accelerate this process of iteration. Since the system in the Northern Hemisphere evolved as a highly specialized adaptation to the cultural, political, and environmental conditions peculiar to those countries over an evolutionary span of about 200 years, it is not clear that it is feasible to expect the less-developed countries to iterate that historic process of industrialization of technology.

The transition from their present deprived condition to one of equality will require surrogates for economically effective demand. This is so because the domestic markets do not possess an economically effective demand at this time, and the probability of quickly establishing technologically based industry of such efficiency that it could compete in an open, worldwide market is very doubtful.

It is at this point that some expression of altruism on behalf of the survival of mankind itself is going to be necessary. In more operant terms, ways of change toward the satisfaction of the desires of the less-developed countries must be found while conserving the integrity of the very system that they seek to emulate. The goal cannot be national self-sufficiency, since worldwide interdependence is the obvious conclusion. Self-reliance, however, is a requirement for human dignity and is the only acceptable condition for interdependence.

In the next few years, a series of international conferences dealing with this problem will be held. Science cannot stand apart from the very industrial and political system that has nurtured it. Science is part of both the successes and the failures in the human experience. Standing by itself, it sorely risks becoming self-indulgent. Just as surely, it must not sacrifice the integrity of its inquiries to those institutions of society that wish to utilize its understanding for the development of technology. The relationship of science to the North-South dialogue is therefore an integral one. It is an inextractable part of the discussion. Like all of the other institutions and elements of that discussion, it is an essential component of it. Like all of the others, by itself it is a futility. At its best, science is the foundation of hope that humanely directed technology may continue to contribute to mankind's well-being. By joining the confrontation with the actual complexities of the North-South dialogue, science can more nearly fulfill its promise.

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