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CONCERNING A NEW INSTITUTION TO ADVANCE TECHNOLOGICAL INNOVATION

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The creation of new technology insures neither the quality nor the quantity of economic or social development. It would appear, especially in recent years, that technological innovation is a necessary, although perhaps not a sufficient, cause for the economic development of an advanced economy. Just as we have seen police protection, fire fighting, education, and social welfare move from private to public responsibility, we are now seeing technological innovation, more particularly nondefense and nonspace technology, move into the area of public responsibility. Military and space technology, and the innovations upon which it depends, has long been accepted as government's responsibility. Given the American institutional pattern, the concept of government financing *all* technological innovation requires a decided change in economic policy. It is precisely because we may be inching in that direction that we must examine not only the consequences, but also the techniques, of effectively utilizing government power in the creation of new technologies.

Relatively recent econometric studies have forced a re-examination of the classical and neoclassical concepts that capital accumulation lies at the heart of growth.[1] These studies permit a shifting of the focus of growth from capital accumulation to organization, and to the "capacity to put scientific and technical information to use."

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Growth, even narrowly defined as increased real income per capita, depends upon those factors which promote or obstruct the creation and diffusion of new technology.[2]

Laws and values in western society hold sacrosanct the preservation and expansion of capital in its traditional concept. In order to utilize the newly recognized power of technological innovation to affect economic growth, it will be necessary to establish new values, new laws, and new institutions which will sanctify technological innovation in the same fashion in which traditional capital has been so thoroughly sanctified by economic conservatives. A new acquiescence to government's aggressive role in obsoleting privately owned capital equipment, and the consequent destruction of existing market shares, must emerge.

Opening the road to the creation and diffusion of significant, even radical, new technology requires some consciousness of the nature of resistances to technological change. Barton C. Hacker quite pointedly has observed that resistance to specific innovations does not really concern itself with the matter of technological usefulness. Resistance comes into play in the perception of an innovation's social consequences, with the actual utility of the innovation taking on a decidedly secondary role.[3] This is true not only with regard to resistance to specific innovations themselves, but also is even more true of resistance to social mechanisms which may accelerate the creation of radical new technologies.

A case in point was the defeat in Congress of the Department of Commerce's 1963 Civilian Industrial Technology Program, which was designed to encourage and support additional research and development in industries which the department regarded as technologically lagging. Industrial groups successfully opposed the bill because, with good reason, they feared that government sponsorship of industrial research and development would upset existing competitive relationships.[4] Although it cannot be documented it is also reported that the recent demise of the State Technical Services Act was supported by the lobbying activities of the National Association of Manufactures. To state the extreme position, one way manufacturers conceivably could avoid the onerous cost of replacing obsolete plant and equipment is to outlaw all research and development. A less effective method, but in the same vein, is to block technology transfer, one of the key factors in achieving technological innovation, and technology transfer is what the State Technical Services Act was all about.

Professor Horace M. Gray, formerly of the University of Illinois, who has been a concerned student of business concentration in the United States for many years, states unequivocally that "Big Business will undertake only such innovations as promise to enhance its profit

and power or protect its market position; it will retard, restrict, or suppress those (innovations) that threaten to place it in jeopardy."[5] Business generally uses its political influence in Congress and in the executive branch to discourage any kind of applied research and development which might add further uncertainty to market conditions, which might hasten obsolescence, or which might introduce an active new class of competitors. It is a naive assumption to believe that industry does not resist having externally controlled technological change thrust upon it.[6]

While basic research provides no threat to market positions, this is not true in the case of applied research and development. At least in theory an alert and active internal corporate research and development program can protect a company's position by effective utilization of government-sponsored basic research. Control of civilian applied research and development, however, is one of the cornerstones of market power, and any suggestion of government performing or funding such research has generally met with strong industrial resistance. The national Chamber of Commerce in its 1965-66 policy declarations states:

> *Applied Research and Development.* Optimum results will be attained by reliance upon the forces of competitive private enterprise in the conduct of applied research and development which seeks to apply the results of basic research to useful end products.[7] To the extent that Federal research is not carefully controlled and is allowed to compete with or inhibit industrial incentive, it can restrain or block economic growth and progress in our free economy.[8]

The sense of this argument is that industrial innovation can more effectively be encouraged by relieving federal restraint, which tends to inhibit investment by industry, than by large expenditures in federally sponsored research and development programs. Examples of constraints on private investment in research and development include "inadequate protection under the patent system, tax rates and structures, restrictive application of anti-trust and trade regulations and antiquated codes which prevent the application of technology."[9]

However inimical to the economic development of a mature economy, impeding the open flow of technology transfer and slowing the pace of research and development may, in fact, protect existing private values in plant, equipment, and market shares. This argument was especially well expressed in a *World Oil* article written by one of its editors: "No single group in industry or government should be allowed to undertake research at random with no

consideration given to economic purpose or possible impact on the industry affected." [10] Applying this philosophy, the owners of stage coaches would have had to approve the experiments of James Watt.

Resistance to radical new technology need not be a conscious conspiracy; it may simply be that laws, values, and the tacit understanding of enlightened self-interest all provide the requisite mechanics. It is a moot point as to whether the predominant portion of the American steel industry was, indeed, criminally negligent in having so long delayed the introduction of oxygen injection furnaces.[11] Adams and Dirlam suggest that both the structural and behavioral characteristics of oligopolized industries *prevent* the dominant firms from pioneering not only in the creation of new technology, but also in the acceptance of its use.[12] They further suggest that, relative to small firms, innovation causes violent disturbances to dominant companies in industry.[13]

If the American automobile industry can, as it has with impunity, escape the consequences of having purposely avoided the development of passenger car safety devices, then who can be penalized for not having discovered, developed, or adopted an invention or a great cost-saving innovation? Minor cost-saving innovations may not be resisted because resultant profits can easily be retained, but major savings may have to be passed on to the consumer or to labor, or such innovations may strengthen weak competitors, particularly in the absence of patent protection.

Maintaining both the status quo and aggressive radical innovation are two mutually exclusive objectives. As important as technological innovation may be to society, the firm well may find greater benefit in the maintenance of the status quo. In fact, the process of institutionalization which puts a premium on maintaining the status quo, may be a necessity for the growth, or even existence, of the large industrial firm. It must be recognized that large firms have other critical concerns beside innovation.

There exists ample evidence to indicate that smallness is no barrier to significant innovation.[14] The small science-based, technologically oriented firm is neither a temporal nor a peripheral economic idiosyncrasy. On the contrary, it is contended that over a span of time it may be one of the most critically important of our economic institutions. The success of such firms, generally in electronics, along Route 128 near Boston and in the Palo Alto area, and the more recent small firm developments in holography in the Ann Arbor area, tend to confirm this contention.[15] It is the never-ending stream of such small firms which may provide the dynamic for maintaining America's favorable technological balance of pay-

ments, and provide for needed social and military innovations as well. Eventually, with growth or merger, the character of the small, science-based, technologically oriented company will change, but new companies can be expected to arise embodying even more novel technological concepts.

Based upon existing comprehensive indexes of output of new technological knowledge, it is claimed that beyond a certain not very large size the bigger the firm the less efficient its knowledge-producing activities are likely to be. It would seem that as the size of the firm increases there is a decrease in the number of significant inventions used commercially per dollar of research and development expended. In support of this position it seems a reasonable claim that the average capabilities of technical people are higher in small firms than in large ones, and that the problems of coordination and communication tend to be less acute in smaller organizations.[16]

The likelihood of the federal government effectively performing civilian research and development in its own laboratories is highly questionable as a matter of efficiency, and totally unacceptable in the light of the American public's fundamental opposition to government ownership of business. Government's role in technology transfer, however, would seem to be an acceptable, even if controversial, vehicle for effecting economic development through accelerated technological innovation. It is contended that the term *technological transfer* is too narrowly defined, and, even more critically, that the term ignores, or at best discounts, the critical nature of the entrepreneurial role without which economic development cannot be achieved within our framework of social and political values.

Technology transfer may be defined as the process whereby technical information originating in one institutional setting is adapted for use, and is successfully used, in another institutional setting.[17] Linking the "communicating-in" of scientific and technical information to the "communicating-out" of such information, and profitably exploiting this relationship, is technology transfer. It is a term that includes both a demand and a supply concept. Government's existing involvement in technology transfer mainly concerns the supply or "communicating-out" aspect, and does little if anything to energize the demand or "communicating-in" aspect. It is here that the myth of the better mousetrap, in a new form, rises to haunt us. The revised myth says: "Show a man (or better still a going firm) the way to build a better mousetrap, and it will be built." Another factor which accounts for the fact that government technology transfer avoids the demand, the "communicating-in" or

the entrepreneurial aspect, is the national paranoia regarding government's involvement in nondefense industry. This tends to block more effective action to energize potential new science-oriented entrepreneurs.

That there is a venture capital market, and that it works, does not mean that the processes of effecting technological innovation cannot be improved upon. The social undertaking of greater technological risk, that which cannot or will not be assumed by the traditional entrepreneur or by the investor, will extend the capacity of the economy to create new products, new processes, and new technologies. When times are bad all risks are to be avoided, and when times are good there are safer places to invest than in technological uncertainty.

The effective transfer of knowledge from basic research to a product or process in the market place is technology transfer, even if a single firm performs the basic research, the applied research, and produces the resulting innovation. The institutional setting of the basic research laboratory is decidedly different from that of the counting house, even within a single firm. This type of transfer may be termed the vertical transfer component. We can also conceive of a lateral or horizontal transfer component. Development opportunities that exist even for well-financed laboratories are innumerable, particularly in atmospheres where research is not required to be rigorously related to narrow product development. The closer management holds research and development expenditures to patently evident profit opportunities within existing manufacturing and marketing capabilities, the greater will be the number of socially useful research and development opportunities foregone. Good business may well dictate the abortion of generally significant bench-scale discoveries.

Rupert Maclaurin, who observed in 1949 that the entrepreneur of the future would be recognized and rewarded for his capacity to be in on new developments at the proper time, and that the determination of cost-price relationships on existing products would be relegated primarily to subordinates, mentions the failure of General Electric and Bell Telephone Company to develop radio.[18] Rather than a failure it was a forfeiture. Both companies were highly research oriented, yet their decision *not* to vigorously explore radio telegraphy in the early 1900s was, *ex ante*, good business judgment. They had other, seemingly more important, eggs that needed hatching. Incidentally, the history of the radio industry is especially interesting because scientists and engineers, with the availability of risk funds, actually did force the pace of technological innovation.[19]

In the face of increasing domestic costs and greatly improved production and research capacity abroad, any new social institution that would accelerate the innovation of new products, new processes, and new technologies is a national *desideratum.* This paper attempts to create a rough outline of a new institution (or social innovation) which, while tending in some ways to conflict with a narrow interpretation of the traditional values of our mixed capitalist economy, does offer a hope for the creation of a new order of magnitude increase in our capacity to effectively innovate. In the exercise of this social innovation it is hoped that America's best minds will be attracted into science and engineering in the realistic expectation that those fields may serve as a means of attaining significant personal wealth. Too often technology transfer, especially when considered mainly as "communication-out," has seemed to be "pushing with a string." The effect of this new step, beyond what is generally considered to be the limit of technology transfer, would be to create a truly effective demand for the transference of technical information.

The conception of Technological Risk Assumption Corporations has its roots primarily in *The New Capitalists,* written jointly by a lawyer and a philosopher.[20] If there is another source for this concept it is in a knowledge of the many successful venture capital projects of the last twenty-five years. The Small Business Administration's Minority Enterprise Small Business Insurance Corporation and some of the policies of the Department of Housing and Urban Development are recent and novel examples of government's utilization of the insurance function to achieve social ends. In considering Technological Risk Assumption Corporations, there is an implied assumption which deserves to be made explicit. It is assumed that American society, or more specifically American science and technology, is a super-saturated solution of technological entrepreneurs, and that compared to the potential the number of practicing entrepreneurs is relatively small. This super-saturation phenomenon exists for a variety of sociological and socio-psychological reasons, but here let it suffice to attribute it to the democratic ideal and to effective public education.

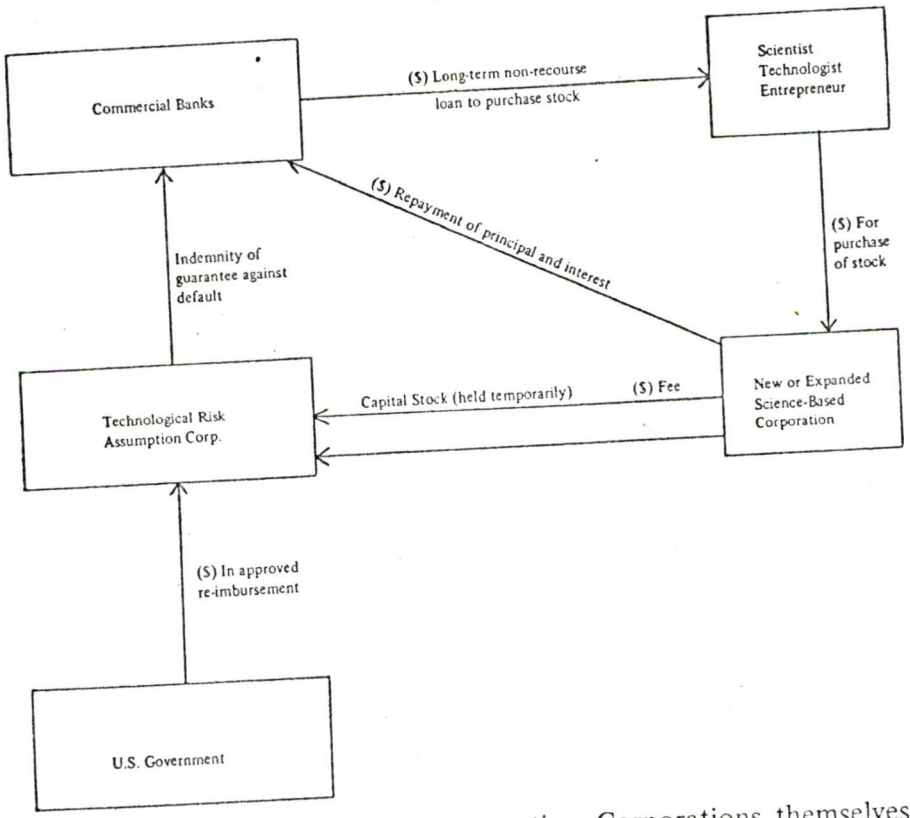
The Technological Risk Assumption Corporation (TRAC) is visualized, in its simplest sense, as an institution which guarantees to commercial banks all funds that those banks will have loaned out for the purpose of initiating and/or maintaining new science-based companies. The borrowing entrepreneurs are visualized primarily as scientists and engineers, but also may include specialized marketing personnel where the need seems critical. The newly issued corporate

stock shall not come into immediate possession of the key people of the new company, but will ultimately be theirs when the guaranteed loans are paid off. The stock would serve as TRAC held collateral against the guarantee of the loan. By contractual arrangement TRAC would exercise stock voting control until such time as the loans are repaid, at which time the stock would go to the owners free and clear. It is an obvious, especially when high rates of interest are involved, and especially critical consideration that what might be normal growth for an ordinary firm would be insufficient growth for a science-based firm financed in this fashion.

The major function of a Technological Risk Assumption Corporation is that of a guarantor. In exercising that function, and, more important, in determining whether or not to enter into any specific guarantee situation, a TRAC must be heavily involved in making short- and long-term forecasts of all kinds (technological, market, financial). Personnel competent to make these decisions must be available to the TRAC. In addition, of course, TRAC, by virtue of their voting control, possess ultimate responsibility for almost all decisions until the bank loans are repaid and the TRAC leaves the picture.

Because of the great risks involved, and as a consequence of the great national benefits that can accrue from the accelerated creation of new technologies, the ultimate guarantor underwriting losses to the TRAC must be the federal government. In addition to payments to the bank of interest and principal, the new science-based companies would pay TRACs a service fee to cover all their costs of operation. TRACs would operate as a federally regulated industry with a federally guaranteed return on the quantity of funds which they, TRACs, would have guaranteed with commercial banks. A sliding return for each TRAC is visualized depending on the extent and quality of its operation. A TRAC with a 100 percent success record could be assumed to be taking insufficient risks. All cash repayments of their losses to TRACs by the government will have to be passed upon by a federal commission created for the purpose of confirming the fact that failure, when it occurred, was due to the consequences of technological risk and not fraud or negligence. This commission would perform a crucial function because it is the only control on the TRACs. The commission would also resolve disputes that might arise between the science-oriented entrepreneurs and the individual TRAC which would be financing them. It is imperative that the TRACs and the government have explicit *a priori* ground rules on what constitutes a justifiable refusal on the part of the government to reimburse TRAC losses.

Figure 1



The Technological Risk Assumption Corporations themselves may be tentatively visualized as departments, subsidiaries, or offshoots of established insurance companies, and staffed with expert personnel in various fields, including scientists and engineers specializing in specific areas or industries. The TRAC may also consist of any firm approved by the federal government and considered strong enough by commercial banks to sustain any nonreimbursible losses as a consequence of fraud or negligence in the science-based company.

Figure 1 is a schematic presentation of the TRAC system based upon the modification of a related plan shown in *The New Capitalism* (page 65).

The first step in the social process is for the scientist-technologist entrepreneurs to convince a TRAC that they can, with available development, engineering, and production funds, create a commercial product or process. The TRAC will guarantee funds, conditional upon sequentially successful steps, for as long a period as

it will take to see the innovation into successful operation. During that rather long initial phase the new firm will possess, from its initial borrowing or credit line, sufficient funds to maintain interest payments, salaries, and TRAC fees.

The government, in the form of a commission set up for the purpose, will supervise TRACs in a manner not substantially different from the Federal Reserve, FDIC, or Controller of the Currency's supervision of commercial banks. One of the more complex problems that the commission would have to deal with is a method for determining at what point additional funds poured into a project would have to be considered fraudulent. However difficult, considering the necessary duplication and the sequential decision-making nature of research and development, it is not an unsolvable problem.

There is no denying that the TRAC system will involve a high cost to the government in unsuccessful projects, but this cost must be measured against the social benefits that can accrue from energizing the creation of socially and financially profitable scientific-based private companies and industries. Introduction of the TRAC system is fully harmonious with a continuation of the present venture capital system of financing new industry. It is also visualized that private capital may buy into science-based companies, and assume the bank loans (and take TRAC off the hook) after much of the early critical uncertainties have been overcome. Furthermore, while we have confined ourselves to newly created science-based companies, the TRAC concept may be broadened to include the expansion of small existing science-based companies with a total, or merely substantial, ownership by technical and managerial personnel directly involved in the operation of the company. A side effect of TRACs may be to further encourage established industries to provide stock options to technological innovators. Fairchild Camera and Instrument Corporation prides itself on "pumping stock options down almost to the laboratory bench."[21]

Detailed contractual relations between all the parties involved in TRAC will be necessary if this system is to live up to the expectation of energizing added dimensions of effort in the creation of new technologies. Many other governments, directly or indirectly,[22] partake of high technological risk investments in the civilian area, often acquiring partial ownership in the enterprise. Our ostensible separation of government and business, in concept more holy than separation of church and state, precludes this course of action. Thus, it is necessary to create a new institution that would achieve the end of accelerated technology creation without departing too violently

from our practice of excluding government from the ownership and operation of producing facilities. Establishment of Technological Risk Assumption Corporations is an indirect attempt to activate entrepreneurial energy in the pursuit of research and development, with eventual equity ownership creating the incentive to scientists and engineers to leave existing jobs and to risk professional reputations.

FOOTNOTES

1. Moses Abramovitz, "Resources and Output Trends in the United States Since 1870," *American Economic Review* (May 1956), pp. 5-23; Benton F. Massell, "Capital Formation and Technological Change in United States Manufacturing," *The Review of Economics and Statistics* (May 1960), pp. 182-88; Robert Solow, "Technological Change and the Aggregate Production Function," *The Review of Economics and Statistics* (August 1957), pp. 312-20.

2. Leonard Silk, *The Research Revolution* (New York: McGraw Hill, 1963), p. 155.

3. Barton C. Hacker, "On the Nature of Controversial Innovation," paper delivered at the Eleventh Annual Meeting of the Society for the History of Technology, Dallas, Texas, (26-29 December 1968); see also *Technology and Culture* 10, no. 2 (April 1969): 198.

4. Edwin Mansfield, *The Economics of Technological Change* (New York: W. W. Norton & Company, Inc., 1968), p. 231.

5. Horace M. Gray, "Technological Determinism as a Defense for Monopoly," *The Quarterly Review of Economics and Business* 5 (Fall 1965): 30.

6. *Ibid.*

7. Chamber of Commerce of the United States, *Policy Declarations 1965-1966* (Washington: Chamber of Commerce, 1966), p. 21.

8. Chamber of Commerce of the United States, Committee on Science and Technology, *Criteria for Federal Support of Research and Development* (Washington: Chamber of Commerce, 1965), p. 5.

9. *Ibid.*

10. Don E. Lambert, "Why Should Taxpayers Finance Consumer-Oriented Research?" *World Oil,* March 1964, p. 13.

11. Walter Adams and Joel B. Dirlam, "Big Steel, Invention and Innovation," *The Quarterly Journal of Economics* (May 1966), pp. 167-89.

12. *Ibid.* p. 188.

13. *Ibid.*

14. W. R. Maclaurin, *Invention and Innovation in the Radio Industry* (New York: The Macmillan Co., 1949); A. A. Bright, *The Electric Lamp Industry: Technological Change and Economic Development, 1800-1947* (New York: The Macmillan Co., 1949); R. Schlaifer and S. D. Heron, *The Development of Aircraft Engines and Fuels* (Cambridge, Mass.: Harvard Business School, 1950); R. R. Nelson, "The Economics of Invention: A Survey of the Literature," *Journal of Business* 32 (April 1959): 108-109. John Jewkes, David Sawers, and Richard Stillerman, *The Sources of Invention* (London: Macmillan and Co., Ltd., 1958); Department of Commerce, *Technological Innovation: Its Environment and Management* (Washington: U.S. Government Printing Office, 1967).

15. Prof. Albert Shapiro of the University of Texas has performed, and is performing, some excellent studies documenting and analyzing this phenomenon. See Kirk Draheim,

Richard P. Howell, and Albert Shapiro, *The Development of a Potential Defense Research and Development Complex: A Study of Minneapolis-St. Paul.* Research and Development Studies Series. (Menlo Park, Calif.: Stanford Research Institute, 1966); Albert Shapiro, Richard P. Howell, and James R. Tombaugh, *The Structure and Dynamics of the Defense Research and Development Industry: The Los Angeles and Boston Complexes.* Research and Development Studies Series. (Menlo Park, Calif.: Stanford Research Institute, 1965).

16. Samuel I. Doctors, *The Role of Federal Agencies in Technology Transfer* (Cambridge, Mass.: The MIT Press, 1969).

17. *Ibid.*

18. W. Rupert Maclaurin, "The Process of Technological Innovation: The Launching of a New Scientific Industry," *American Economic Review* (March 1950).

19. *Ibid.*

20. Louis Kelso and Mortimer Adler, *The New Capitalists* (New York: Random House, 1961).

21. "Top Idea Men Trade Ideas," *Business Week,* 31 January 1970.

22. In England the government-owned National Research Development Corporation. "The Corporation's development work is concerned with new inventions, including proposals for technological innovation, which in the opinion of the Corporation are not being furthered sufficiently and require to be supported in the public interest. The extent of the support ranges from the assumption of all the responsibility and finance involved to that of its sharing with one or more other parties." *National Research Development Corporation, Report and Accounts for the year ending 31st March 1969,* p. 4.

In Israel the Ministry of Commerce and Industry will supply 50 percent of the funds of approved private civilian industrial research projects. In addition, the government owns a half interest in the Israel Research and Development Corporation, which finances the creation of science-based industries.

Boston Globe

Nixon asks US–business partnership to spur technology

By Sterling F. Green
Associated Press

WASHINGTON —President Nixon proposed to Congress yesterday a sweeping program of tax aids, credit help and liberal application of the antitrust laws to stimulate a partnership effort of government and business to develop new and usable technologies.

In a special message to Congress, Mr. Nixon said the fruits of accelerated research and development should be applied to solving the nation's social and economic problems and bolstering American leadership in trade competition.

"I am therefore calling today for a strong new effort to marshal science and technology in the work of strengthening our economy and improving the quality of our life," Mr. Nixon said.

"And I am outlining ways in which the Federal government can work as a more effective partner in this great task."

Mr. Nixon said the partnership will bind together the Federal government, private enterprise, state and local governments and university research centers in a cooperative effort to promote the national interest.

The message unveiled some of the recommendations of a White House office on technology created six months ago, which has been sifting proposals developed by some 300 persons assigned to the task in a score of Federal agencies.

Mr. Nixon's budget message in January called for a substantial increase in Federal outlays for government research and development, including a redirection of some military, space and atomic energy research to serve civilian needs.

The message listed some of the targets:

—New sources of energy without pollution.

—Fast, safe, pollution-free transportation.

—Measures to reduce the loss of life and property from earthquake, hurricanes and other natural disasters.

—Improvement of drug abuse rehabilitation programs and curb drug trafficking.

—Increasing research efforts aimed at cures for cancer and heart disease and other killer ailments, as well as improving health care systems.

Mr. Nixon, in calling on Congress to provide tax encouragement and subsidies for private research and development, said it frequently is impossible to bring needed innovations into use through normal market mechanisms.

"For example, the sheer size of some developmental projects is beyond the reach of private firms, particularly in industries which are fragmented into many small companies," the President explained. In other cases, he said, the risks of some projects would be excessive for individual firms.

He listed these measures of Federal support and encouragement:

Antitrust—The antitrust laws should be applied in such a way, Mr. Nixon said, as to permit companies to combine their financial and technological resources to meet the costs of developing new products or processes and to share jointly in the earnings. He suggested this as a proper guideline for the application of the anti-monopoly statutes:

"In general, combinations which lead to an improved allocation of the resources of the nation are normally permissable, but actions which lead to excessive market power for any single group are not.

"Any joint program for research and development must be approached in a way that does not detract from the normal competitive incentives of our free enterprise economies."

Credit — To encourage development of small, high-technology firms, which have distinguished records for innovation, Mr. Nixon asked Congress to strengthen the ability of small business investment companies (SBICs) to funnel capital into such firms. He proposed that the current limit on government support to SBICs increase, and that the present ceiling on Small Business Administration loans be increased to $20 million.

Mr. Nixon also urged that commercial banks be permitted to own up to 100 percent of an SBIC rather than 50 percent as at present.

Taxes — Mr. Nixon called for passage of the Small Business Tax bill which would, among other things, extend to 10 years the period in which he is firm can apply a loss against its future earnings for tax purposes.

Other tax incentives would be included, such as extending the period in which qualified stock options can be exercised from five years to eight or 10 years, and reducing the holding period for unregistered stock from three years to one year.

Patents — The private use of government-owned patents would be liberalized. The Patent Office would make such patents available through private firms with exclusive rights to protect the user during the period in which he i risking large sums to bring the product to market. Without such protection, he would be vulnerable because any other firm could enter the field.

Prizes — The government will establish a new program of research and development prizes. The President will award them for "outstanding achievements by individuals and institutions," particularly to encourage innovation in major areas of public need.

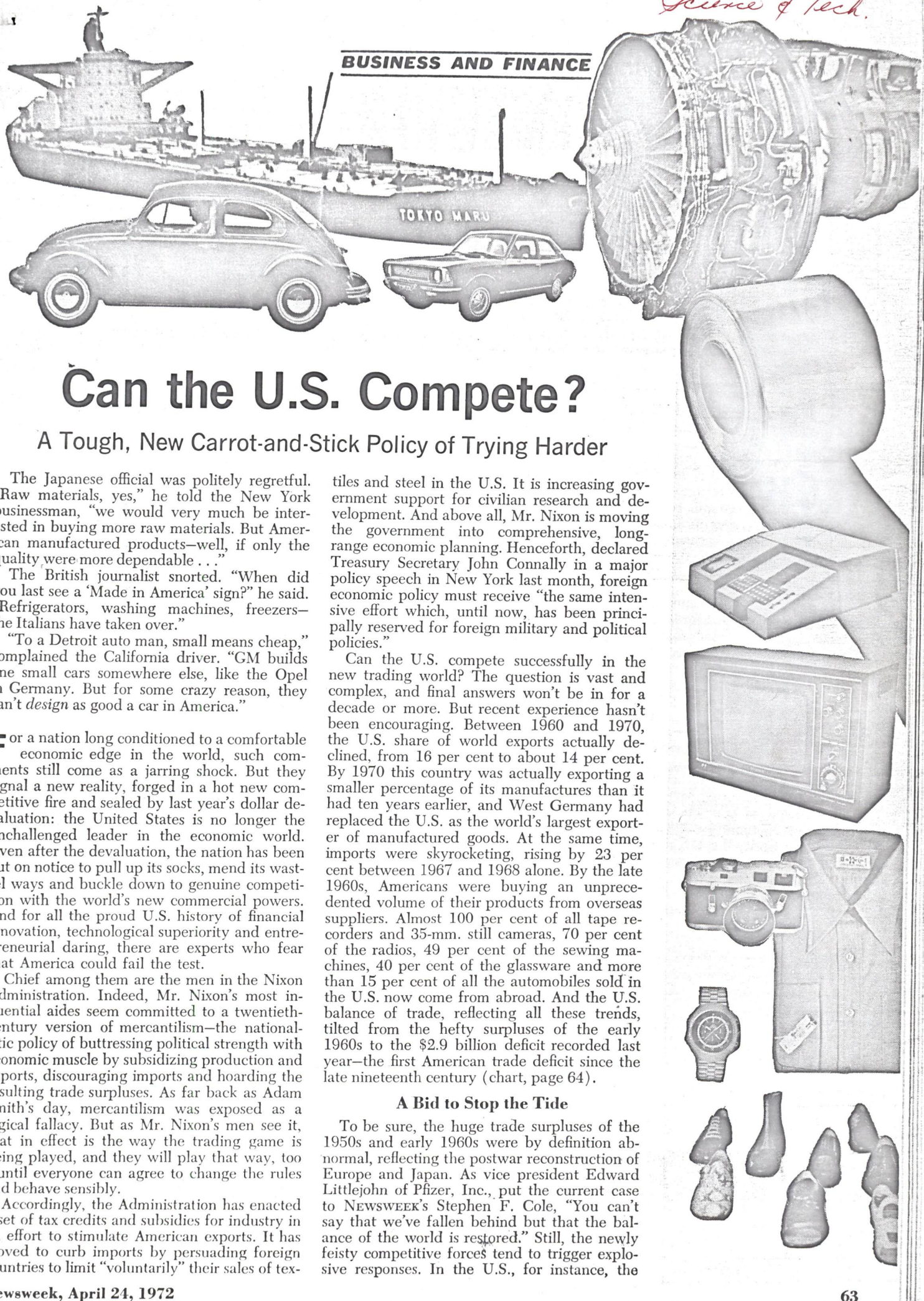
Experimental programs — A variety of partnership arrangements among government agencies, private firms and universities will be set up to test their feasibility in promoting private investment. New arrangements will be tried out for cost-sharing, patent licensing, and research support.

Metric system — Mr. Nixon called for enactment of legislation which would permit gradual transition to the metric system of measurement. He called this "an important step which could be of great significance in fostering technological innovations and enhancing our position in world trade."

Review of Technological Opportunities

	PSAC or Consultant	OST Staff
1. Transportation		
(a) Reduction in urban traffic congestion	Simon and Truxal	Luenberger
(b) Cleaner, quieter, safer transportation	"	"
Unconventional power supplies for autos	R. Gouse (with Simon)	Moe (with Balzhiser)
(c) Increased transportation productivity		
Northeast corridor improvements	Fitch	Martin
Aircraft developments	R. Miller	Drew
2. Communications for social needs		
-- Electronic mail service	Olsen	Drew and Noll
-- Health care	Smith	Laster
-- Educational and cultural service	Truxal	Mays
3. Natural resources		
(a) Water resources		
Water resources in agriculture	N. Brady	Caldwell
River basin management	L. Dworsky	Butcher
(b) Mineral resources	E. Gilliland	Balzhiser
(c) Continental shelf	W. Nierenberg	Blake
(d) Forest productivity	N. Brady	Caldwell

	PSAC or Consultant	OST Staff
4. Urban/Suburban development		
-- Housing and urban development	Moynihan and Coleman	Luenberger
-- Integrated utility system	L. Roddis	Gage
5. Productivity		
(a) International competitiveness	Haggerty	Neureiter
(b) Technologies for productivity improvement	Haggerty	Noll (with Beckler)
(c) State commerce extension	"	Beckler (with Luenberger)
(d) Ocean platforms, ship automation	Buchsbaum	McRae
6. Health care		
-- Health care delivery	Smith	Laster
-- Nutrition	Bennett	Caldwell
7. Air quality		
-- Waste management pilot plant	Cairns	Balzhiser
-- Advanced power cycle	Tape	Weinhold
-- Regional modelling of pollutants	Friedman	Blake
-- Health effects	N. Nelson	Burger
8. Protection from natural disasters		
-- Weather warning and modification, including forest fire supervision	W. Kellogg	Blake
-- Earthquake warning	F. Press	"
-- Standards for community action	Simon	Blake (with Lannan)



Can the U.S. Compete?

A Tough, New Carrot-and-Stick Policy of Trying Harder

The Japanese official was politely regretful. "Raw materials, yes," he told the New York businessman, "we would very much be interested in buying more raw materials. But American manufactured products—well, if only the quality were more dependable . . ."

The British journalist snorted. "When did you last see a 'Made in America' sign?" he said. "Refrigerators, washing machines, freezers—the Italians have taken over."

"To a Detroit auto man, small means cheap," complained the California driver. "GM builds fine small cars somewhere else, like the Opel in Germany. But for some crazy reason, they can't *design* as good a car in America."

For a nation long conditioned to a comfortable economic edge in the world, such comments still come as a jarring shock. But they signal a new reality, forged in a hot new competitive fire and sealed by last year's dollar devaluation: the United States is no longer the unchallenged leader in the economic world. Even after the devaluation, the nation has been put on notice to pull up its socks, mend its wastrel ways and buckle down to genuine competition with the world's new commercial powers. And for all the proud U.S. history of financial innovation, technological superiority and entrepreneurial daring, there are experts who fear that America could fail the test.

Chief among them are the men in the Nixon Administration. Indeed, Mr. Nixon's most influential aides seem committed to a twentieth-century version of mercantilism—the nationalistic policy of buttressing political strength with economic muscle by subsidizing production and exports, discouraging imports and hoarding the resulting trade surpluses. As far back as Adam Smith's day, mercantilism was exposed as a logical fallacy. But as Mr. Nixon's men see it, that in effect is the way the trading game is being played, and they will play that way, too—until everyone can agree to change the rules and behave sensibly.

Accordingly, the Administration has enacted a set of tax credits and subsidies for industry in an effort to stimulate American exports. It has moved to curb imports by persuading foreign countries to limit "voluntarily" their sales of textiles and steel in the U.S. It is increasing government support for civilian research and development. And above all, Mr. Nixon is moving the government into comprehensive, long-range economic planning. Henceforth, declared Treasury Secretary John Connally in a major policy speech in New York last month, foreign economic policy must receive "the same intensive effort which, until now, has been principally reserved for foreign military and political policies."

Can the U.S. compete successfully in the new trading world? The question is vast and complex, and final answers won't be in for a decade or more. But recent experience hasn't been encouraging. Between 1960 and 1970, the U.S. share of world exports actually declined, from 16 per cent to about 14 per cent. By 1970 this country was actually exporting a smaller percentage of its manufactures than it had ten years earlier, and West Germany had replaced the U.S. as the world's largest exporter of manufactured goods. At the same time, imports were skyrocketing, rising by 23 per cent between 1967 and 1968 alone. By the late 1960s, Americans were buying an unprecedented volume of their products from overseas suppliers. Almost 100 per cent of all tape recorders and 35-mm. still cameras, 70 per cent of the radios, 49 per cent of the sewing machines, 40 per cent of the glassware and more than 15 per cent of all the automobiles sold in the U.S. now come from abroad. And the U.S. balance of trade, reflecting all these trends, tilted from the hefty surpluses of the early 1960s to the $2.9 billion deficit recorded last year—the first American trade deficit since the late nineteenth century (chart, page 64).

A Bid to Stop the Tide

To be sure, the huge trade surpluses of the 1950s and early 1960s were by definition abnormal, reflecting the postwar reconstruction of Europe and Japan. As vice president Edward Littlejohn of Pfizer, Inc., put the current case to NEWSWEEK's Stephen F. Cole, "You can't say that we've fallen behind but that the balance of the world is restored." Still, the newly feisty competitive forces tend to trigger explosive responses. In the U.S., for instance, the

Robert Ritter

tide of imports has unleashed a wave of protectionism among threatened industries and organized labor, which argues that 1 million or more jobs have been lost to cheap foreign wage rates. At the extreme, such protectionist measures as the current Burke-Hartke bill could plant a forest of trade barriers around the U.S., touch off retaliatory measures by other nations and curb both the growth of world trade and the expansion of American industry abroad.

Not that the protectionist danger is one-sided. Commerce Secretary Peter C. Peterson is also worried that the European Common Market is becoming a protectionist bloc with an expanding set of preferential arrangements that will exclude U.S. goods from some of the world's major markets. And Peterson is concerned that the nation may not be able to pay for the massive imports of raw materials and fuel supplies that it will require in the not-so-distant future.

At bottom, however, Mr. Nixon's men see the need to compete as a political imperative. Without a solid source of income from trade, the U.S. might not be able to continue both its corporate investment overseas and its vast military expenditures all over the world—a combination that accounted for an $11.5 billion drain in the U.S. balance of payments last year. "If you're in a competitive decline, you can't go on splashing out that sort of money," warned one British economist recently, and the Administration clearly agrees. When friends ask CIA director Richard Helms whether he worries more about potential slippage in the American diplomatic or military positions, he answers: "I worry more about our economic position. If we can't hack it economically, we're not going to hack it any way." And Peterson reminded NEWSWEEK's Rich Thomas recently: "It is hard for any country without economic strength to have any political influence."

For all these alarms, it is far from clear that the U.S. is in any long-term trading trouble at all—and there is no lack of optimists to proclaim their faith. "I really feel there are lots of opportunities," says William P. Doolittle, vice president of Hewlett-Packard Co. in Palo Alto, Calif. "It's just up to American industry to accept the challenges. We haven't got a chance if we sit back and cry and say the other fellow has an advantage."

In this view, most of the deterioration of the American position came during the late 1960s—mainly because of the economic effects of the Vietnam war. The rapid escalation of 1965 overheated the economy, producing a burst of domestic demand and a steep rise in U.S. imports. And the wartime inflation coincided with a slowdown in other major countries that cut into the demand for U.S. exports, exaggerated the swing in the trade balance and kept a lid on wage demands by overseas workers. The impact of all this on U.S. labor costs was startling: while labor cost per unit of output had actually declined in the first half of the decade, it soared by 21 per cent in the next five years (chart, below), raising prices of U.S. products on the world's markets and paving the path for new waves of foreign imports.

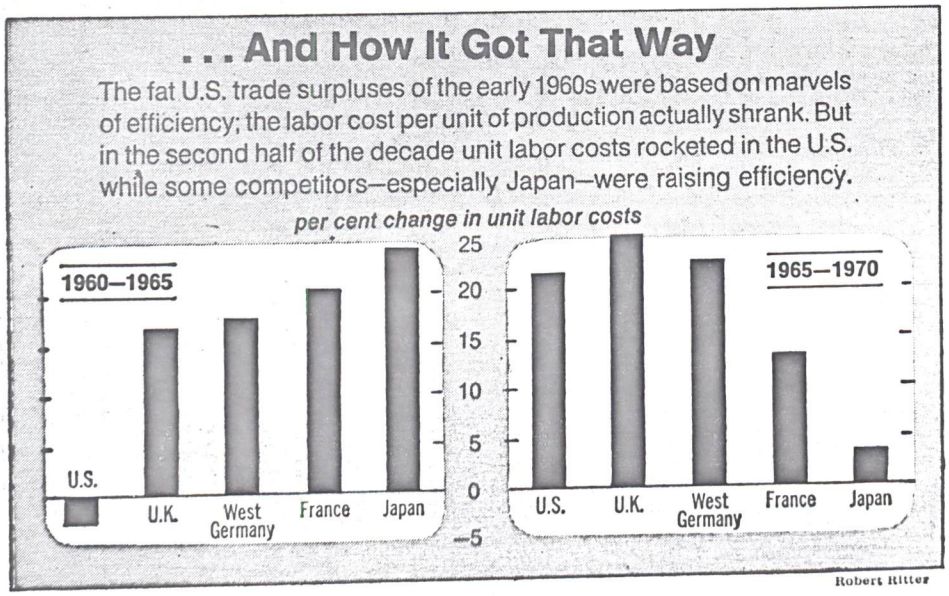
Hopefully, that burst of inflation is being checked by Mr. Nixon's wage and price controls—and if so, the normal pattern is that the U.S. has always run a slower rate of inflation than other major countries. Indeed, there are signs that the past is already reasserting itself. In Europe last year, unit labor costs rose from 6 per cent in France to 14.5 per cent in Italy, compared with only 2.5 per cent in the U.S., and German manufacturers have had to raise prices four times in the last two years just to keep up with rising wages. Ironically, cries are now being heard within Europe that the Europeans are pricing themselves out of world markets.

The Blessings of Going Broke

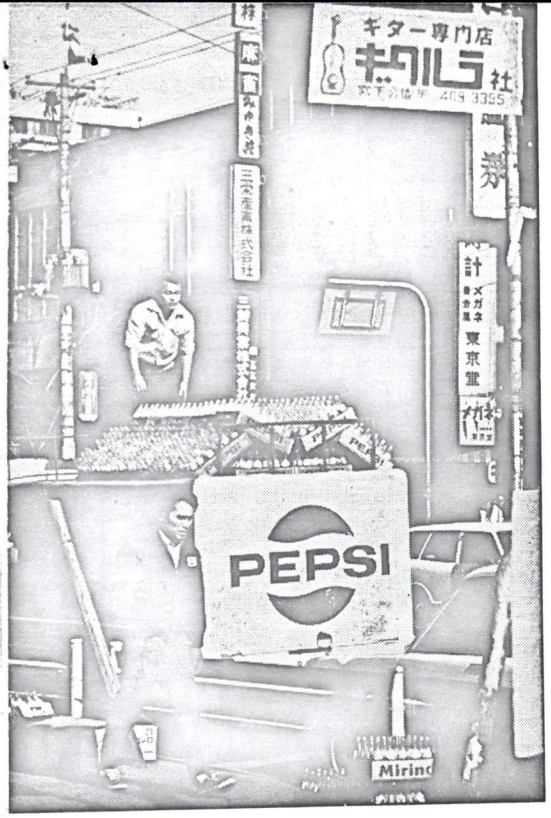
In large part, the improving U.S. outlook reflects the effects of last year's devaluation—a move that makes U.S. exports cheaper in terms of foreign currencies at the same time it raises the dollar price of foreign goods on the U.S. market. Historically, it takes two to three years for a devaluation to have its full effect on trade. But U.S. export orders have already shown a decided rise. American companies have just edged out Japanese competitors for a power-generating contract in Guam, and in the Ivory Coast, U.S. interests outbid Japanese contractors three weeks ago to build a $63 million sugar-cane development project. Japanese television manufacturers say that U.S. demand for their products is declining because of their higher prices, and national forecasts indicate that European export growth will nose downward in 1972.

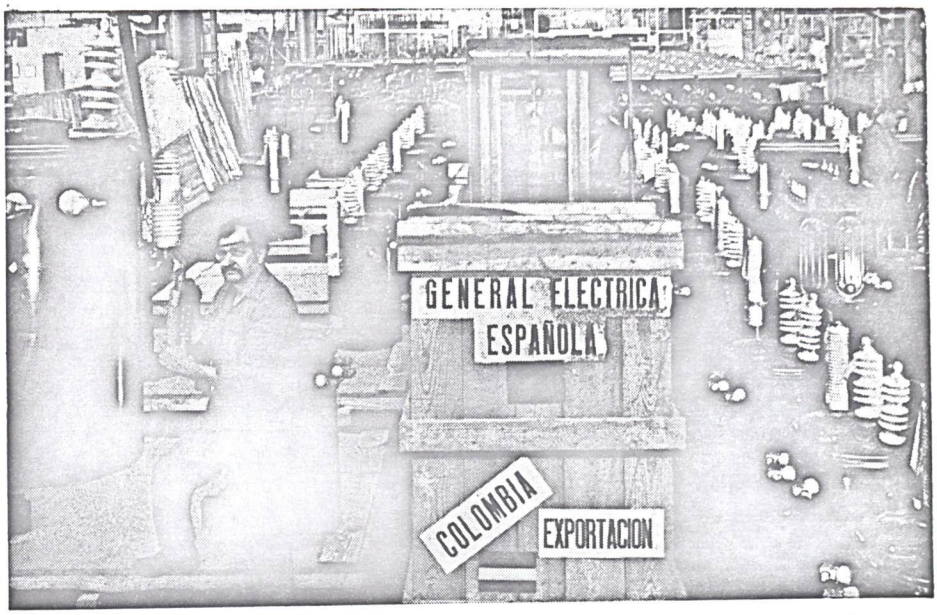
The narrowing gap in costs has also persuaded a leading Swiss company to consider manufacturing large electrical generators in the U.S., and American officials in Europe report a sharp upswing in inquiries about opportunities for foreigners to invest in the U.S. And in a startling reversal of recent history, American officials in Tokyo even see a market there for American consumer goods such as recreation equipment and kitchen appliances. Says one U.S. aide: "When you take a visiting American businessman through a department store here, his eyes light up when he sees some of the price tags." "The only problem," adds a Japanese economist, "is trying to inter-

(Continued on Page 66)



Robert Ritter





The multinational corporations: More investments, fewer exports?

(Continued from Page 64)

est these American firms in exporting."

The benefits of devaluation, however, are only one reason for optimism about long-term U.S. trading prospects. In truth, the U.S. has never competed primarily on prices, relying instead on unique products, quality controls and advanced technology to sell goods. And while there are signs that the technological lead is dwindling, there are still dozens of areas, from agriculture to nuclear generating plants, where the U.S. remains supreme. Indeed, U.S. technicians are mounting successful counterattacks to recapture lost markets. Several years ago, the Japanese seized upon U.S. transistor technology and used it to dominate the market in electronic calculators. But this month a small California company, Commodore Business Machines, will begin marketing a desktop calculator in Tokyo that undercuts Sony's price for a comparable model. And Hewlett-Packard's new battery-powered HP-35 pocket calculator, priced at $395 and built around miniaturized integrated circuits, is designed to compete with a desktop Japanese model priced at $1,500.

The U.S. also has a strong lead in the exporting of services, from banking and accounting to food handling, franchising and management consulting. And although these "invisible" exports don't show up on the usual trade-balance figures, they can be expected to grow increasingly important as the U.S. economy becomes less focused on physical production and more attuned to services.

In fact, the trend to service exporting may well be the U.S. path to long-term success. The trade balance itself is important largely by hallowed tradition, and a surplus there is useful mainly to offset red ink in other accounts. Barring a mindless return to mercantilism by all the world's nations, nobody really wants to pile up ever-increasing surpluses at the expense of others. The goal for all is a rough equilibrium in each nation's total balance of payments. And as many economists now see it, the U.S. is in the process of becoming a "mature creditor" nation that can finance chronic deficits in trade with its invisible exports of services and the dividends it gets from overseas investments. The U.S. is already earning more than $7 billion a year in investment income, and by 1975 this sum may grow to $17 billion in dividends, fees and royalties. Other nations argue that they will need to sell more than they buy from the U.S. if they are going to be able to pay that bill.

Making Less, Enjoying It More

Although the trend implies a decline in many U.S. manufacturing industries, a number of economists argue that it will actually result in more jobs in higher-paying, more satisfying high-technology areas and in the services. "Of everything we consume," says economist Lawrence Krause of the Brookings Institution, "physical products are going to be a declining portion, imports or not." And in this view, it would be inefficient folly to spend U.S. money to subsidize the continued production of something that other nations could produce more cheaply. As Princeton economist William Bransen puts it, recalling the recent textile agreements setting "voluntary" quotas on imports from the Far East: "I hate to see our relations with Japan endangered to save an industry that ought to be phased out anyway."

But if this is the trend of the future, it is bound to be a long time ripening. In the real world, such theoretical truths tend to make slow headway against the realities of a domestic textile lobby, the strategic needs of the Defense Department and the shifting alliances of Presidential politics. Moreover, there is a nest of very real and intertwined uncertainties that makes forecasting more than usually hazardous. Until these questions are answered, it would be rash indeed to ignore the downward drift of the trade balance and assume that everything will somehow come out all right. The main unknowns:

■ **Trade barriers.** Although the U.S. probably has more tariffs, quotas and non-tariff barriers on industrial products than the Common Market has, the Administration complains that the European Economic Community's agricultural policy has resulted in a loss of $200 million to $400 million each year in U.S. agricultural exports. And Washington figures that the 1965 U.S.-Canadian auto agreement, which contains a number of "safeguards" to prevent Canadians from buying American-made cars, has turned a U.S. auto-trade surplus of $562.8 million in 1964 into an estimated deficit of $300 million in 1971. Even more irritating is the vast complex of protectionist devices surrounding Japan, which are especially rigged against imports of manufactured goods. Unless such trade barriers are lowered, they will continue to distort the world's trade figures—but the major nations have only recently agreed even to discuss the issue.

■ **Multinational corporations.** In the past ten years, major American corporations have focused less on exports than on building plants and producing goods overseas. Between 1960 and 1970, for example, the value of American investments abroad rose from $32 billion to $78 billion, and almost 3,600 American companies now have at least one plant overseas. According to AFL-CIO chief economist Nat Goldfinger, fully 25 per cent of all U.S. trade today consists not of transactions between a U.S. company and foreign nationals but transfers between divisions of these multinational corporations—with the type of goods and their

prices determined by the company's internal needs and tax considerations, rather than by the dictates of international competition.

The largest multinationals have recently publicized a torrent of studies, attempting to head off controls by proving that their investments actually stimulate American exports, but the labor unions and many economists are convinced that U.S. manufacturers abroad not only displace exports but export jobs as well. Until more is known about how multinational investment influences trade and productivity, long-range policy can't be set.

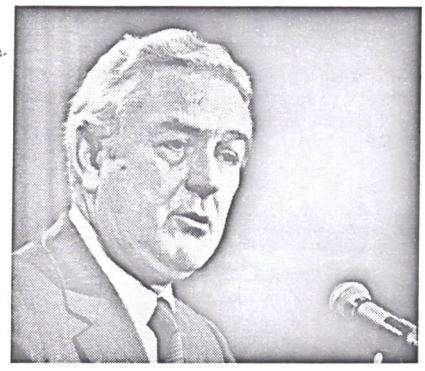
■ **Productivity trends.** Before the dollar devaluation, American workers still turned out at least 20 per cent more goods and services per man-hour than workers in other leading nations. But that gap had already narrowed sharply during the late 1960s. Some analysts argue that the relative decline was only a temporary result of the business cycle, as U.S. companies overinvested during the Vietnam boom and allowed their work force to swell and sag. They point out that productivity registered a strong 3.6 per cent increase last year and is expected to show another big advance as economic recovery continues in 1972. But pessimists fear that more basic structural trends are at work, reflecting a decline in high-productivity jobs and a new lack of will to work hard and compete (box, page 65).

■ **The technology gap.** Historically, U.S. manufacturers have competed successfully against cheaper foreign goods only by maintaining a constant flow of new, technologically advanced products, from the sewing machine to the computer. As Prof. Ray Vernon of Harvard has pointed out, America's trade problems center in older industries that have lost their innovative drive, such as clothing and steel, or in products like vitamins and transistors in which the U.S. has lost a technological advantage to foreign imitators. Yet he and many others see evidence that the time lag between the introduction of a new product and its diffusion to manufacturers around the world—the period in which innovators can exploit their lead—is growing shorter. "When I was in business in the early 1950s," an American official in London said recently, "we used to allow five years before the Europeans would catch us up. By 1963 it was about two years and now it might be less than one year in some cases."

Even worse, some experts believe that the traditional U.S. lead in advanced technology may be eroding. To be sure, the U.S. has spent hundreds of billions of dollars on research and development over the past twenty years, and total R & D expenditure today is close to $30 billion a year—three times that of Western Europe and eight times that of Japan. But the U.S. may be getting too little bang for its buck. Many research dollars, and most of the skilled manpower, have been devoured by the military for research with little practical application. And civilian R & D, as a percentage of GNP, lagged behind efforts of Western Europe and Japan in the last decade.

Given all these worrisome unknowns, the dominant forces within the Administration have begun a major new drive to make sure that, whatever the ultimate answers, the U.S. will not fritter away its economic muscle. And entirely apart from the trade issue, some of the steps they are taking will clearly be beneficial to the nation.

The Commerce Department, for example, is trying to anticipate the long-range economic future by projecting U.S. raw material and fuel requirements over the next fifteen years and planning ways to insure that those needs will be met. The Administration also plans to invest in the future with its "technology-enhancement" programs, which include $40 million in seed money for civilian research and development, a re-examination of U.S. patent policy to encourage



Photos by Wally McNamee—Newsweek

Connally, Peterson: One in the eye for the State Department

WHO RUNS U.S. TRADE POLICY?

The question of whether the U.S. can compete not only divides the nation's experts but underlies a sharp new rift within the Administration itself. Under the aggressive leadership of John Connally, supported by Secretary of Commerce Peter G. Peterson, the Treasury Department is trying to gather all of the tangled reins of foreign economic policy into its own hands for the long, tough drive to restore America's competitive superiority. The principal object of Connally's wrath is the State Department, which he has publicly implied is a nest of "ponderousness" and "in some sectors, innocence," and the antagonism has grown so hot that Connally has told colleagues that he would like to cut State entirely out of the crucial trade and monetary talks that lie ahead.

Some coordination of the foreign economic policy apparatus is clearly necessary; Harald Malmgren, one of the two newly appointed U.S. trade negotiators, estimates that there are now at least 60 conflicting authorities in that field. But as State sees it, Connally's move is a naked power play. "Let's face it," says one senior diplomat, "Connally is trying to dominate U.S. foreign economic policy. He is a very strong man, but he has tunnel vision. Economic policy is just one aspect of over-all American relations abroad; it is not an end in itself." Connally's rough handling of traditional European allies has these officials particularly incensed. "All this talk that we've been taken in by our allies, all this behavior as if we're blind adversaries, is just unprofitable posturing. It's worse, because it gets everyone mad," snaps a former State official.

Still, Connally and Peterson insist that State is soft on trade issues. One high Administration source close to Commerce recalls that some of State's commercial attachés, asked to send in detailed reasons why U.S. industry was not selling more to their countries, sent elaborate explanations and defenses of all the foreigners' nontariff barriers. "You know in your heart that the State Department is on your side," he comments, "but sometimes you just have to wonder."

Wrangle: At the moment, the focus of the battle is the Commerce Department's effort to assume new authority over the commercial attachés in U.S. embassies abroad. This wrangle has now gone to a special committee headed by President Nixon himself, and it seems that State will probably retain nominal control of the attachés, although they will report directly and continuously to Peterson as well as to State.

On the negotiating front, Connally has succeeded in bringing both trade and monetary policy under his own command. Temporarily at least, the State Department is maintaining a discreetly low profile, and even such a notable bureaucratic infighter as Henry Kissinger has agreed that Connally should carry the ball in economic negotiations. Barring an upset, he will get his way.

WALL STREET

MAKING IT OVERSEAS

BY CLEM MORGELLO

If American industry is becoming less competitive, can investors capitalize on that trend?

It may sound unpatriotic, but there are numerous ways it can be done—and, in fact, is being done—although they present problems of their own.

One obvious way is to buy the stock of a company that is giving its U.S. competitors a hard time. And, judged by American standards, there are tempting bargains overseas. Focusing on Japan, cause of a great portion of U.S. trade woes, Arthur Lipper Corp. comes up with these interesting comparisons: Eastman Kodak's earnings have risen 21 per cent during the past five years and its stock sells for 45 times earnings, but Fuji Photo's profits have jumped 199 per cent and it sells for only ten times earnings; Caterpillar's net has gone down 15 per cent and it sells at 24 times earnings vs. a 48 per cent gain in net and eleven times earnings for Komatsu, a comparable Japanese firm; and General Motors, with an 8 per cent profits gain in five years, sells at thirteen times earnings while Toyota, with a 160 per cent rise in profits, sells at an only slightly higher fourteen times earnings.

LACK OF INFORMATION

Some foreign stocks are available in the U.S.—listed on the exchanges or sold over-the-counter—but investors must buy them overseas in most cases. Either way, notes Dimitri Villard of Havenfield Corp., "American investors won't get the same degree of information that they're used to in this country." This handicap is compounded if the trading is done in overseas markets, Villard adds, because they aren't nearly as liquid as the U.S. market and they are more vulnerable to sharp declines on bad news. In addition, notes Alexander Schwartz of Bache & Co., an American who buys a foreign stock pays a price penalty. If he buys it from a foreigner, he must pay the interest-equalization tax of a bit more than 11 per cent. And if he buys it from an American owner, he pays a premium price. Last week, for example, American-owned shares of Matsushita closed at $27.50 on the New York Stock Exchange while foreign-owned shares went for only $25.

If these problems deter an investor, there's another tack that he can take: buy the stock in American firms that have import and distribution agreements with foreign companies. For example, Amco Industries is the exclusive distributor of Toyota cars and trucks in fourteen states; Geon Industries distributes replacement parts for 95 per cent of the foreign cars in the U.S. and Telecor, Inc., has exclusive marketing rights to Panasonic products in twelve states. Many of these stocks have performed very well. For example, Telecor is selling at more than three times its 1970 low and Amco is selling for almost five times its 1970 low.

RENEWAL PROBLEM

But there's a problem, here, too, notes Leo Lancer of Bruns, Nordeman: distribution contracts expire, and there's always the chance that they may not be renewed. Lancer cites the case of Superscope, a onetime hot stock that is sole U.S. distributor for much of the Sony consumer electronics line (but not its TV sets). Superscope took on the Sony line when it was little known in the U.S., but it's now tangled up in lawsuits with Sony, raising doubt that its distribution agreement will be renewed before it expires at the end of 1974.

There are still other ways to try to capitalize on the competitive gains and faster growth rates of foreign companies. The Lipper Corp.'s Arthur Lipper III suggests "the portfolio route"—investing in mutual funds or closed-end funds that hold foreign securities. There are many mutual funds in Japan, his area of prime interest, but Lipper is not impressed with their performance. So he suggests funds based outside Japan—such as this country's Japan Fund and Canada's CSM Fund. On still another tack, Maurits Edersheim of Burnham & Co. believes "multinational companies are the way to go . . . the best way to play growth abroad." Firms such as IBM, National Cash Register and CPC International have, indeed, taken advantage of overseas expansion and now receive 50 per cent or more of their net from abroad.

The ultimate insult, of course, is to try to capitalize on the growing uncompetitiveness of U.S. industry by selling short the stock of a company that is suffering from foreign competition. But luckily for such companies, short selling goes against the grain of most investors.

THE WEEK'S ACTION — APRIL 10-14

	Close	Point change
DOW JONES *Industrials*	967.72	+5.12
NYSE *Composite*	61.28	+.20
AMEX	28.53	+.22
NASDAQ *Composite*	133.88	+2.08

Volume in millions of shares

NYSE 99.5 AMEX 31.4 NASDAQ 55.2

private exploitation of government-owned patents and a search for foreign patents that could be adapted here.

Commerce has also embarked on a massive export-promotion drive, aimed primarily at the small and medium-sized U.S. companies that have never been export-minded. Overseas sales promotions have intensified, and Peterson has launched an intensive research program to produce solid information as to which American goods have potential export markets. The Administration has also increased the lending authority of the Export-Import Bank, and according to Harold Scott, Assistant Commerce Secretary for International Trade, the U.S. can now match "the commercial credit provided by our major competitors."

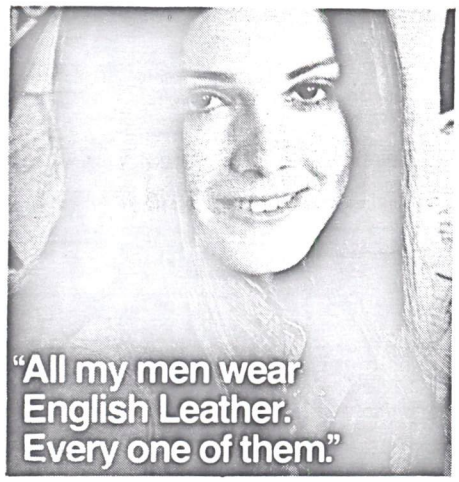
The Controversial Counterattack

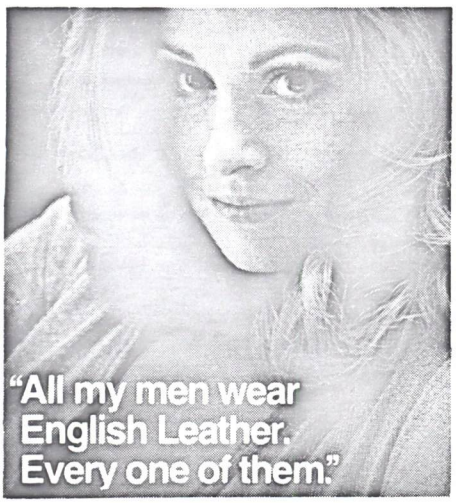
To hold the outright protectionists at bay, the government has also revitalized its enforcement of the Anti-Dumping Act, designed to prohibit foreign manufacturers from selling their products at lower prices here than in their home markets. And to soften the blow of import competition, the Nixon group is preparing a long-overdue bill that would make it easier for injured communities, companies and workers to receive adjustment assistance, such as job retraining or aid in obtaining a new industry to fill a vacant plant.

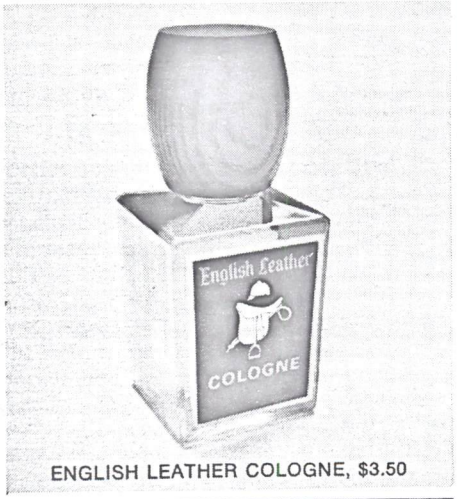
So far, so good. But other weapons in the Administration's arsenal are far more controversial, and could wind up being costlier than any C-5A. Last year's investment tax credit, the acceleration of depreciation and a new law that allows companies to defer taxes on their export income will cost the Treasury an estimated $6.2 billion in lost revenues, with no assurance at all that the measures will actually increase either exports or productivity. Many experts believe that such programs simply amount to enormous giveaways, draining public funds that are badly needed for pressing domestic problems. "What we are doing is economically wasteful," says economist Lawrence Krause. "This crazy export-promotion business can only benefit the shipping business."

Moreover, the Administration's insistence on lumping together negotiations on trade liberalization and world monetary reform, with the aim of using the reform issue to extract more trade concessions, has isolated the U.S. from all of its major allies. Last week, for example, Under Secretary of the Treasury Paul Volcker was bluntly told in Tokyo that the Japanese and Europeans agree that the trade talks should be conducted separately. Nonetheless, Connally is holding firm. "We did all right with parities last fall but we did not do well in the other areas," says one of his aides. "Ultimately, we simply have to have an over-all forum in which trade, monetary reform, aid and defense are all considered as one."

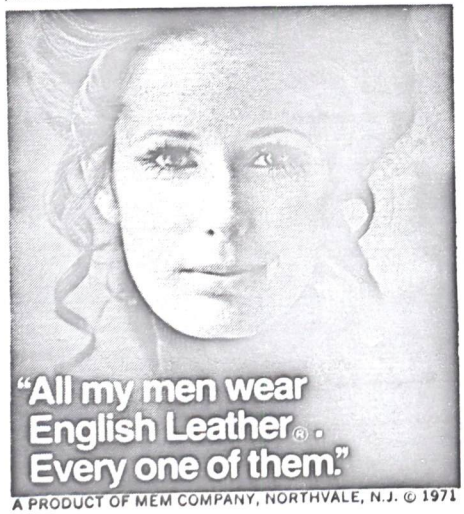
Government spokesmen defend these







ENGLISH LEATHER COLOGNE, $3.50



A PRODUCT OF MEM COMPANY, NORTHVALE, N.J. © 1971

controversial tactics by insisting that "the law of the marketplace is the law of the jungle," as Scott puts it. "It doesn't do any good for us to say to our competitors, 'Stop cutting your prices'," he says. "While we talk, they will go on doing all the business. We have to become idiots like them, and give tax concessions on exports like they do. At some point, they may be willing to agree that we're both idiots and then agree to cut it out."

"That is just no sensible way to run international affairs and policy," replies Krause. "The U.S. has to provide the leadership away from this nonsense, not toward it." Economic nationalism, as Krause and others see it, can only injure the world's consumers; for the U.S. to take up that cudgel now would be to fight a futile delaying action against its own economic trends. If the nation is indeed becoming a "mature creditor country," it will more than ever need a cooperative world with free flows of goods and capital.

In logic and sense, of course, free trade has been the best possible answer ever since Adam Smith's day—and it has always been shunted aside for military or diplomatic reasons. Its time may be coming, but it will be hard for any U.S. Government to divorce the economics of trade from the Pentagon's requirements or, say, from the power of Arab nations to shut off the oil faucet if they don't like U.S. policy in the Middle East. In the meantime, whether the U.S. can compete will continue to depend on a host of unpredictable factors, ranging from the mood of Japanese bureaucrats to the price of corn in Iowa—and the only real way to measure the net total lies in the marketplace. "Are we competitive? Only the market can tell you that," says a former State Department official. "We've just had a big exchange-rate change; now let's see what the market tells us." Adam Smith himself couldn't have said it better.

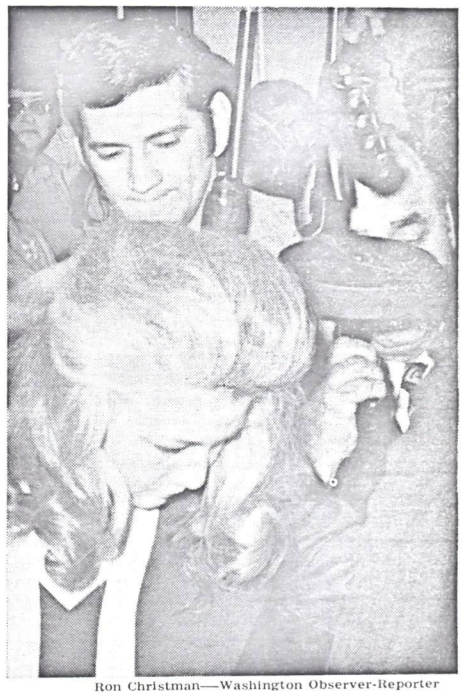
LABOR:

Again, the Coal Murders

Who put up the money for the killing of Jock Yablonski?

More than two years after the insurgent United Mine Workers leader and his wife and daughter were murdered in their beds and almost a year after a scruffy small-time hood confessed to the crime, the question still hung over the Appalachian coal fields. For Claude Vealey's confession, in addition to implicating two other gunmen, Paul Gilly and Aubran Martin, had told of a $5,200 payoff for the slaying and hinted vaguely that it came from a man named "Tony." Yablonski had been running to oust W.A. (Tony) Boyle from the union's presidency, but the connection stopped there —and Boyle indignantly denied that he had had anything to do with the crime or the killers.

The next step came with dramatic suddenness last week. In a decaying, 100-year-old courthouse in Washington, Pa., a tiny coal town only a few miles from the Yablonskis' old stone farmhouse in Clarksville, Paul Gilly's wife, Annette, pleaded guilty to charges that she had conspired in the slayings. A day later, FBI agents arrested William J. Prater, 52, a field representative for the UMW's District 19, on charges in connection with the killings. But it wasn't until the following day that special prosecutor Richard Sprague set off the biggest stick of dynamite in the case thus far by producing a sworn, 22-page statement, given to FBI agents by Annette Gilly during



Ron Christman—Washington Observer-Reporter

Mrs. Gilly: A line to 'the big man'

nine days of interrogation earlier this month, that linked the murder of Yablonski to still higher levels within the UMW hierarchy—possibly to Boyle himself. "My father [Silous Huddleston, a former minor UMW official who goes on trial this week as a conspirator in the affair] told me that the Yablonski murder had the approval of the 'big man'," the hard-faced, 32-year-old blonde said in her statement to the FBI. "To me, that meant Tony Boyle, president, United Mine Workers."

Final Link? Much of Annette Gilly's statement was based on hearsay from her father and husband, and the union high command, meeting in New York, promptly denied her allegations. But investigators said they had given Mrs. Gilly a lie-detector test on virtually every line of her statement, and she apparently passed with flying colors. For turning state's evidence, she has been promised immunity from the electric chair—a tactic that Sprague hopes to pursue along the chain of conspiracy until he finds the final link. "The death penalty does have some effect," he said wryly.

In her statement, read in open court

TOO MANY U.S. WORKERS NO LONGER GIVE A DAMN

In assessing America's faltering competitive stance in the world, one disturbing conclusion stands out: a prime reason for the U.S. troubles is that all too many American workers—particularly young ones, who are supposed to be bubbling with energy and ambition—no longer give a damn. Whether they are overworked or overprivileged, pampered or oppressed, dehumanized by the demands of their jobs or just plain bored—whatever the reason—the evidence is strong that the traditional work ethic of the U.S. is showing signs of senility.

This worker malaise has resulted in absenteeism rates as high as 20 per cent on Fridays and Mondays in some automobile plants, forcing management to rustle up part-time student help to keep the assembly lines going. Quality suffers and costs soar with inexperienced help—or due to outright sabotage by angry workers. Blue-collar workers are not the only ones affected; as just one example, until it took steps to correct the situation, McDonald Corp., the Chicago-based fast-food outfit, was experiencing a 100 per cent turnover in its office force every two years.

Dropouts: The problem traces to two main factors: a younger work force—25 per cent of which is under 25 years old—and the nature of work itself in a highly industrialized society. "It's mainly a problem of this younger worker," said Benjamin Aaron, director of the Institute of Industrial Relations at UCLA. "He doesn't want to work to get ahead; he wants to work to get enough money for a while and then he wants to drop out." Or, as Jerry Wurf, president of the American Federation of State, County and Municipal Employees, put it: "The Depression is something they learned about in a history class."

Once on the job, workers all too often find that, however good their wages and working conditions, work is a totally unsatisfying experience. "People my age don't take much pride in this work," says Victoria Bowker, a 27-year-old blueprinter at Lockheed Aircraft. "In the old days, you used to start a job and you used to finish it. Now things have become so diversified you can't see your product; you start something and it goes through 50 million other hands before it's completed." Mike Eckert, a longtime Lockheed employee twice Miss Bowker's age, agrees that things have changed. "Today's management doesn't have any compassion for the person that's down the line," he says. "They treat you like a machine ... and you can't treat human nature that way." And when a worker begins feeling like a machine, he'll probably resort to one of two alternatives: goldbrick, or start looking for another job. "I'll tell you how attitudes are," UAW vice president Ken Bannon summed up last week. "You will find people who say they would rather work in cleanup and take a cut of 15 cents an hour than work the assembly line. At least on cleanup you have the choice of sweeping the pile in the corner or sweeping the pile by the post."

Alan Dunn; © 1968 The New Yorker Magazine, Inc.

Your office won't take 'the general malaise' as an excuse

College students rarely face such unpleasant alternatives—and yet many of them, too, are thumbing their noses at traditional work values. "You talk to almost any graduating senior in college today, and one of the first things he says to you is that he doesn't want any of those 9-to-5 jobs," says UCLA's Aaron. "They're not afraid to work; if they get enthusiastic about something they'll work like hell. But there's this feeling that the old way just isn't the best way any more." "There is no nationwide pattern on campus," according to Richard Gummere, a Columbia University counselor. "There are as many conventional middle-class types who are just as interested in upward mobility as there were ten, 50 or 100 years ago. It's simply more fashionable to challenge it today." But a survey for the John D. Rockefeller 3rd Foundation recently turned up the fact that only 39 per cent of a national sampling of students believe that "hard work will always pay off," compared with 69 per cent who felt that way just four years ago. Moreover, only 36 per cent of the students said they wouldn't mind being bossed around on the job; in 1968, 56 per cent said they were willing to submit to authority.

What's to be done? "I think the key is involvement in work," says Arnold Judson, an organizational behavior specialist with Arthur D. Little, Inc. "This ranges from keeping the worker informed of what's going on to actual participation in decision making. It's a lot of crap to say that workers are slothful and indifferent today. It's just the opposite; they want to do satisfying work. Why otherwise would you see people going into craftwork and learning skills that involve pride in workmanship?"

Blues Beaters: But such an approach cannot be the whole answer in mass-production industries where, after all, it is impossible to stay competitive without mass-production methods. Yet even here efforts are being made to wipe out the blue-collar blues. Ford Motor, for example, is experimenting with a "team" approach to building some auto components with workers moving along the line and handling the project from start to finish. Chrysler Corp. has a similar job-enrichment program under way. Workers in one plant were allowed to run their own department while the foreman was on vacation; at another location workers themselves test-drove cars they had built. In the white-collar area, Chicago's McDonald Corp. has sharply slashed its turnover rate since moving into its ultramodern new headquarters in Oak Brook, Ill., which features such fringe comforts as a "think tank" where harassed executives (or their secretaries) can take time off the job to relax on 700-gallon water beds.

Such innovations are difficult to make, if only because managers hate to give up the illusion that they control the workers under them. But as General Motors learned in its automated plant at Lordstown, Ohio, the benefits of efficiency can vanish quickly in strike losses when the workers are unhappy. "In terms of international competition," sums up U.S. Labor Department manpower-expert Neal Herrick, "we've ridden technology as far as it will carry us. Now we need to apply some more human methods of management if we are to improve our productivity."

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MEMORANDUM

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January 8, 1973

TECHNOLOGY ASSESSMENT

Technology Assessment Office Established To Advise Congress on Probable Beneficial and Adverse Impacts of Technological Applications; Likely Impact on Industry Discussed

Introduction

To help anticipate the consequences of technological applications on existing and emerging national problems, the 93d Congress and succeeding Congresses will be assisted in their work by a newly established Office of Technology Assessment. This important development is attributable in large part to increasing congressional frustration over its limited staff and information-gathering ability which have made it dependent upon the executive agencies for virtually all its information and evaluative materials. In this light, the 92d Congress passed, and the President signed into law, the Technology Assessment Act of 1972 (P.L. 92-484).

Briefly, the Act establishes an Office of Technology Assessment (OTA) as an exclusive arm of the legislative branch of the Government to help the Congress improve its ability to evaluate legislation which embodies scientific and technical proposals. The OTA will be governed by a bipartisan 13-member Technology Assessment Board consisting of six Members from each House of Congress, plus a Director who will be a nonvoting member of the Board. Because of some apprehension that over-zealous assessment might stifle technological research and development, the bill was amended in the Senate to provide public input for the activities of the Office by establishing a 12-member Technology Assessment Advisory Council whose composition and duties are described below.

Since the Office of Technology Assessment will not be responsible for developing legislation but only for advising the Congress on the implications of technological developments and alternative applications, its operations will not directly affect industry. Moreover, it should be stressed that the Office's basic function is informational and not regulatory. The Office's indirect impact, however, is no less noteworthy since it will advise the Congress--which appropriates over one-half of the nation's R&D funds--on which emerging or existing technologies are likely to be most beneficial to society and which might lead to undesirable or unanticipated consequences.

This memorandum reviews the legislative background of the new technology assessment law, outlines its major provisions, presents a current report on the new Office's organizational status and plans, and makes some preliminary speculations as to its possible impact on industry. It also includes as an Appendix the Summary and Conclusions of a Report of the National Academy of Sciences entitled, "Technology: Processes of Assessment and Choice."

Background

Rationale for legislation.--A number of legislative proposals were offered over the last five years which would have established a technology assessment capability for the Congress and an extensive hearings record was developed during this period documenting the need for such a mechanism. The major impetus for the present legislation is referred to above and is spelled out in the statement of purpose in the Act as follows:

> (a) As technology continues to change and expand rapidly, its applications are--
>
> (1) large and growing in scale; and
> (2) increasingly extensive, pervasive, and critical in their impact, beneficial and adverse, on the natural and social environment.
>
> (b) Therefore, it is essential that, to the fullest extent possible, the consequences of technological applications be anticipated, understood, and considered in determination of public policy on existing and emerging national problems.
>
> (c) The Congress further finds that:
>
> (1) The Federal agencies presently responsible directly to the Congress are not designed to provide the legislative branch with adequate and timely information, independently developed, relating to the potential impact of technological applications, and
> (2) the present mechanisms of the Congress do not and are not designed to provide the legislative branch with such information.
>
> (d) Accordingly, it is necessary for the Congress to--
>
> (1) equip itself with new and effective means for securing competent, unbiased information concerning the physical, biological, economic, social, and political effects of such applications; and

> (2) utilize this information, whenever appropriate, as one factor in the legislative assessment of matters pending before the Congress, particularly in those instances where the Federal Government may be called upon to consider support for, or management or regulation of, technological applications./1

The action of the Congress in establishing OTA is also a response to a growing public concern about the use and misuse of technology. Testifying in favor of the bill's enactment, former Congressman Emilio Q. Daddario, an early proponent of the concept of technology assessment and now in private industry, succinctly observed:

> The public is now extremely sensitive to the use of technology and has become somewhat antagonistic to it because it believes we apply our technology haphazardly. Much more will be demanded of government in this area in the future and this legislation will add to the public confidence that we are not only concerned but taking action./2

Industry comment.--While most industry spokesmen who testified on the technology assessment legislation favored the concept, many also pointed out the dangers as well as the benefits. A recurrent theme was the concern that technology assessment not be permitted to become a tool to inhibit research and development. As one industry representative commented: "The national concern is and properly should be to question the consequences of applying the technology, not of exploring the technology. Legislative concern about producing, distributing, and regulating the technology should trigger formal assessment exercises, but only when the facts and insight resulting from a mature R&D effort are available."/3 The question raised here regarding the timing of assessment studies was not explicitly addressed in the law and, therefore, the controlling factor most likely will be the pressures brought on the Congress and the Board on particular subjects. The principal congressional sponsors of this legislation have publicly stated that they view the role of OTA as a "positive program" to advance orderly scientific development, not as a mechanism to impede technology. In addition to the Board's bipartisan composition which is intended

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1/ 86 Stat. 797 (P.L. 92-484).
2/ U.S. Congress, Senate Committee on Rules and Administration. Hearings before the Subcommittee on Computer Services on S.2302 and H.R. 10243, March 2, 1972, p. 71.
3/ Ibid, p. 106 (Statement of Harold H. Hall, Vice President and Chief Technical Officer, Aerospace and Marine Systems Group, The Singer Company).

to minimize partisan influence, the Board is expected to work closely in its operations with a statutory advisory group composed of public and technical members, including representatives from industry. Whether these safeguards will be effective in practice only time and experience will tell.

Major Provisions of the Law

Establishment and duties of Office.--The Act creates the Office of Technology Assessment which is "within and responsible to" the legislative branch of the government. The Office is to consist of a Technology Assessment Board (described below) which will formulate and promulgate the policies of the Office, and a Director appointed by the Board who is to carry out the policies and administer the operations of the Office.

The basic function of the Office, as noted earlier, is to provide early indications of the probable beneficial and adverse impacts of the applications of technology and to develop other coordinate information which may assist the Congress. In carrying out such functions, the Office shall:

(1) identify existing or probable impacts of technology or technological programs;
(2) where possible, ascertain cause-and-effect relationships;
(3) identify alternative technological methods of implementing specific programs;
(4) identify alternative programs for achieving requisite goals;
(5) make estimates and comparisons of the impacts of alternative methods and programs;
(6) present findings of completed analyses to the appropriate legislative authorities;
(7) identify areas where additional research or data collection is required to provide adequate support for the assessments and estimates described in paragraphs (1) through (5) above, and
(8) undertake such additional associated activities as the appropriate authorities/1 may direct.

1/ The law specifies that assessment activities undertaken by the Office may be initiated upon the request of (1) the chairman of any standing, special, or select committee of either House of Congress, or of any joint committee of the Congress, acting for himself or at the request of the ranking minority member or a majority of the committee members; (2) the Board; or (3) the Director, in consultation with the Board.

The Office of Technology Assessment by law shall not itself operate any laboratories, pilot plants, or test facilities but may enter into contracts and other arrangements with private contractors and government agencies to carry out the duties of the Office.

Technology Assessment Board.--The Board is composed of thirteen members as follows:

(1) six Members of the Senate, appointed by the President pro tempore of the Senate, three from the majority party and three from the minority party;

(2) six Members of the House of Representatives appointed by the Speaker of the House, three from the majority party and three from the minority party; and

(3) the Director, who shall not be a voting member.

The Chairman and Vice Chairman of the Board are to be selected from among its members at the beginning of each Congress. As is the case with other joint congressional bodies, the chairmanship and vice chairmanship will alternate between the Senate and the House of Representatives each Congress.

A significant grant of power is given the Board in authorizing it subpoena power, upon a vote of a majority of its members, to require the attendance of such witnesses and the production of such books, papers, and documents as it deems advisable. It is important to note, however, that the Board, and only the Board, is authorized to use the subpoena power. This provision was insisted upon by the House Conferees so as to ensure that the subpoena power could not be transferred to the Director or any person not an elected member of Congress. Although documents can be subpoenaed, their disclosure to the public is protected under the Act by Section 552(b) of Title 5, United States Code (exemption relating to trade secrets and commercial or financial information obtained from a person and privileged or confidential). The Board may make such rules respecting its organization and procedures as it deems necessary, except that no recommendation shall be reported from the Board unless a majority of the Board assent.

Technology Assessment Advisory Council.--At the insistence of the Senate, the conference committee adopted an amendment calling for the establishment of an Advisory Council to be composed of twelve members:

(1) ten members from the public, to be appointed by the Board, who shall be persons "eminent in one or more fields of the physical, biological, or social sciences or engineering or

experienced in the administration of technological activities, or who may be judged qualified on the basis of contributions made to educational or public activities";

(2) the Comptroller General; and

(3) the Director of the Congressional Research Service of the Library of Congress.

It is intended that one or more members of the Advisory Council will be selected from the ranks of business.

The Advisory Council's duties are broadly defined. Upon request by the Board, the Council shall:

(1) review and make recommendations to the Board on activities undertaken by the Office or on the initiation thereof;

(2) review and make recommendations to the Board on the findings of any assessment made by or for the Office; and

(3) undertake such additional related tasks as the Board may direct.

The Chairman and Vice Chairman of the Council are to be selected by majority vote of its members and shall serve for such time and under such conditions as the Council may prescribe.

The term of office of each member of the Advisory Council is four years. No person is to be appointed a member of the Council (from among the ten public members) more than twice. Also, the terms of the public members of the Council shall be staggered so as to establish a rotating membership.

It is our understanding that no appointments to the Advisory Council have been made to date.

Relationship with other agencies.--Special arrangement is made for cooperative activities and supporting services to be provided to OTA by the Library of Congress and the General Accounting Office, both of whose chief officials will be members of the Advisory Council. OTA is also directed to maintain a continuing liaison with the National Science Foundation whose ongoing program in Research Applied to National Needs is partially devoted to the development of technology assessment techniques. Also, the National Science Foundation Act of 1950 is amended to permit the Foundation to undertake the support of research requested by OTA.

Availability of information.--Assessments made by the Office, including information, surveys, studies, reports, and findings related thereto, shall be made available to the initiating committee or other appropriate committees of the Congress. In addition, any such information, surveys, studies, reports, and findings produced by the Office may be made available to the public except where (1) to do so would violate security statutes, or (2) where the Board considers it necessary or advisable to withhold such information in accordance with one or more of the numbered paragraphs in Section 552(b) of Title 5 of the United States Code.

Appropriations.--To enable the Office to carry out its powers and duties, the Act authorizes the appropriation of funds not to exceed $5,000,000 in the aggregate for the two fiscal years ending June 30, 1973 and June 30, 1974. Legislation implementing the appropriations authorized is expected to be submitted early in this Congress.

Current Organizational Status

Technology Assessment Board.--The twelve voting members of the Technology Assessment Board have been appointed and are as follows:

Senate

Edward M. Kennedy (D.-Mass.)	Clifford P. Case (R.-N.J.)
Ernest F. Hollings (D.-S.Car.)	Peter H. Dominick (R.-Colo.)
Hubert H. Humphrey (D.-Minn.)	Richard S. Schweiker (R.-Pa.)

House

John W. Davis (D.-Ga.)	Charles A. Mosher (R.-Ohio)
Olin E. Teague (D.-Tex.)	Charles Gubser (R.-Cal.)
Mike McCormack (D.-Wash.)	James Harvey (R.-Mich.)

Senator Kennedy has been chosen as the first Chairman of the Technology Assessment Board and Representative Davis as Vice Chairman.

Director of OTA.--The Director of OTA, who will be a nonvoting member of the Board, has not yet been named. His selection will be a priority item on the agenda of the Board's first organizational meeting later this month.

Advisory Council.--The Technology Assessment Advisory Council to be established by OTA will be named at an early meeting (but probably not the first meeting) of the Board. The Council's selection is being given deliberate consideration by the Board and an informal sounding of the National Academy of Sciences and the American Association for the Advancement of Science has been made to elicit advice on the Council's composition. These two organizations have been consulted not so much to recommend particular candidates, but rather to provide advice on the kinds of expertise the Council should have. As noted earlier, the public members

are to be persons distinguished in a number of fields broadly related to technology, and it is expected that there will be some industry representation on the Council.

Projected assessment studies.--Although no announcement has been made concerning early assessment projects to be undertaken by OTA, possible assessment topics mentioned at the hearings include the following: automation and computer technology, weather modification, social and economic effects of new auto propulsion systems, urban transit, new food technologies, and the nonmilitary effects (such as on cities and employment) of new military technologies.

A specific illustration of the kind of assessments which may be undertaken by the Office is suggested by the example cited in Senator Kennedy's testimony at the hearings on the bill in which he discussed the need for assessment of an important new technological development--"the advent of cheap solid-state devices for the generation of microwaves." Referring to an article in Scientific American, Senator Kennedy noted that microwave devices will soon be marketed at such prices that car telephones will become as common as car radios, automotive radar systems will be developed to avert collisions, and a host of other applications will be forthcoming. "The net result of these developments over the coming decade will be to vastly increase the amount of microwave radiation to which people are exposed. The article states 'there is no doubt that microwave radiation can be harmful to living organisms, but there is considerable controversy over the levels of irradiation required to produce significant effects.'" Thus, Senator Kennedy concludes, "The time to find answers to these questions is now, not after individual microwave devices pervade our economy. The purpose is not to prevent new developments of this sort from occurring, but to assure that they are channeled so as to achieve the maximum benefit for society."/1

Impact on Industry

While the activities of the Office of Technology Assessment will not have a direct impact on industry, the indirect impact through legislation influenced by its assessments may be significant and, in some cases, could be adverse. The impact of an assessment which results in Congress restricting funds for R&D on the development and marketing of a technological application dependent on such funds is obvious. Equally clear are the dangers inherent in premature assessments which, if based upon incomplete knowledge or guesswork, might stifle technological innovation.

On the other hand, it should be stressed that OTA has no authority to dictate or even to recommend to the Congress what it should do about

1/ U.S. Congress, Senate Committee on Rules and Administration. Hearings before the Subcommittee on Computer Services on S. 2302 and H.R. 10243, March 2, 1972, op. cit., p. 38.

technological innovations. OTA can only report on the likely consequences and alternatives of a technological innovation; legislative action is solely the prerogative of the appropriate congressional committees.

Also, there are positive impacts which technological assessments produced by OTA might have for industry. This would be the case if, as suggested by the Act's sponsors, the Office identifies promising technological applications and is influential in speeding up their development.

Conclusion

There obviously can be no objection to the Congress being better informed on the technological impact of legislation which it must consider. An improvement in the quality of public debate and legislation through a better understanding of the many variables involved in technological applications is all to the good. However, there is considerable merit in the caution expressed by the President's former Science Advisor, Dr. Lee A. du Bridge when he testified in favor of the assessment concept: "How to identify and then flag, at the appropriate time, the relevant set of a multitude of potential problems is the real challenge of a technology assessment mechanism."/1

* * *

Comments from member company executives on the possible long-range implications of this legislation would be appreciated.

1/ U.S. Congress, House Committee on Science and Astronautics. Hearings before the Subcommittee on Science, Research, and Development, November 18, 24; December 2, 3, 4, 8, and 12, 1969, p. 122.

A P P E N D I X

Technology: Processes of Assessment and Choice, A Report of the National Academy of Sciences/1

Summary and Conclusions

The members of this panel are persuaded that mechanisms for technology assessment beyond those currently operating are clearly needed. Although technology-assessment activities are already widely dispersed among government instrumentalities and private organizations, it is our conclusion that such activities suffer in their totality from basic inadequacies that will prove increasingly critical as the scale and intensity of technological development continue to mount.

Our study has revealed that existing mechanisms, whether they involve government agencies, private industries, or professional groups, possess intrinsic limitations, some structural and others psychological, that leave serious gaps in the spectrum of processes that assess and direct the development of technology in our society: In the formulation of issues for assessment and in the attribution of value to alternative outcomes, those processes too often ignore the broader social and environmental contexts in which their effects are felt. In the calculation of costs and benefits, they ascribe too little significance to the preservation of future options. They give too little attention and support to research and monitoring programs calculated to minimize technological surprise and to deal more rationally with the burdens of uncertainty. They frequently reflect the views, interests, enthusiasms, and biases of unduly narrow constituencies and create insufficient opportunities for meaningful public participation in choices having major public consequences. And they manifest too little concern for the evolution of consistent principles in the formulation and enforcement of assessment criteria.

The reasons for these shortcomings are complex and varied. In part, the difficulties are conceptual--inadequacies in analytic tools and in theoretical understanding; failures of imagination; deficiencies of data; the sheer technical difficulties of perceptive and precise evaluation. In greater measure, the problems are institutional--economic, legal, or political constraints upon the interests that each individual decision-maker is encouraged to treat as his own; limits upon the representation of varied interests in collective processes of decision; constraints upon the coordination and focusing of pertinent efforts. These difficulties cannot be overcome at a single stroke; but they can gradually be reduced by a program of technology assessment that is broader in fundamental conception and scope than any now existing, one that takes into account the changing values, sensitivities, and priorities of society.

1/ U.S. Congress, House Committee on Science and Astronautics, July 1969.

The present organization of private and public assessment systems is too fragmented and uncoordinated, too lacking in professionalism, continuity, and detachment, to provide a viable institutional basis for the support of the research and education that a sufficiently broad technology-assessment program will demand and for the development of the professional competence and vision that such a program will require. No institution or group of institutions is today charged with the responsibility, or equipped with the resources, to review the criteria and assumptions, monitor the operating procedures, and integrate the findings, of our many technology-assessment efforts--even those undertaken within the federal government--or to stimulate the development of a set of coherent principles that might increase the quality and influence of such efforts and enhance their sophistication.

Although we recommend the creation of new institutions in the federal government to perform these integrating functions of review and stimulation, we acknowledge that the present multiplicity of technology-assessment processes is both desirable and necessary. Technological development pervades so many aspects of contemporary life that no limited number of organizations devoted to technology assessment could competently span the enormous range of relevant activities. Thus we do not contemplate in this report or foresee in the future a highly centralized process of technological evaluation, even for the areas of technology that are largely dependent upon federal programs and policies. Such centralization would be not only unworkable but unwise, politically unacceptable, and extremely dangerous. Thus new institutions are needed not to supersede existing mechanisms but to supplement them.

With these principles in mind, the panel urges the creation of a constellation of organizations, with components located strategically within both political branches, that can create a focus and a forum for responsible technology-assessment activities throughout government and the private sector. Limited at the outset to those areas of technology that are strongly and directly influenced by federal policy, such organizations must be separated scrupulously from any responsibility for promoting or regulating technological applications and must have the authority and resources for:

1. Undertaking substantial in-house studies to evaluate trends in technology and in technology-assessment practices; to examine the operations of existing assessment mechanisms; to establish priorities for technology-assessment efforts; and to derive policy alternatives and recommendations from research.

2. Supporting major research activities in external organizations with respect to technical issues arising in the course of specific assessments and theoretical issues pertinent to the improvement of the intellectual base for technology assessment in general.

3. Encouraging activities and programs related to the stimulation of public awareness of, and interest in, assessment issues and the education and development of professional groups with broadened perspectives to staff future technology-assessment activities in industry, in government, and in other institutions.

It is the panel's hope that, out of a set of mechanisms capable of performing these functions, there will evolve a consistent and influential body of assessment principles, derived not only from conscious attempts to formulate general policy but also from experience with individual cases selected in part for their precedent-setting potential. Although limited at its inception to federally supported or regulated technologies, the program we envision could, over time, inspire parallel efforts at other levels of government, from the local to the international, and in the private sector as well.

However our specific recommendations might be viewed, the members of this panel are convinced that some form of constructive action is imperative and that such action cannot be long delayed without greatly increasing the difficulty of its implementation and significantly diminishing the prospects for its success. The future of technology holds great promise for mankind if greater thought and effort are devoted to its development. If society persists in its present course, the future holds great peril, whether from the uncontrolled effects of technology itself or from an unreasoned political reaction against all technological innovation.

Engineering Outline 249 UDC 654.17

Facsimile telegraphy

Key indexing words
analogue method
binary method
carrier channels
communications
photo cells
recording

by G D Skingle, CEng, Group Leader, Telegraph and Facsimile Transmission, Post Office Development Department.

Definition and introduction

Facsimile telegraphy is the name given to the process of converting information recorded on a sheet of paper, be it typescript, map, diagram or newspaper into an electrical signal for transmission over a telephone line or other telecommunications media and its subsequent reconversion at the receiver to produce, ideally, an exact copy of the document transmitted. The telephone line may include physical pairs of wires, carrier channels, or radio circuits or combinations of these in tandem. For high-speed facsimile use is made of other wider frequency band transmission facilities available in the telecommunications network.

Unlike television, facsimile telegraphy is only used for the transmission of individual pictures or documents each of which requires several minutes for transmission.

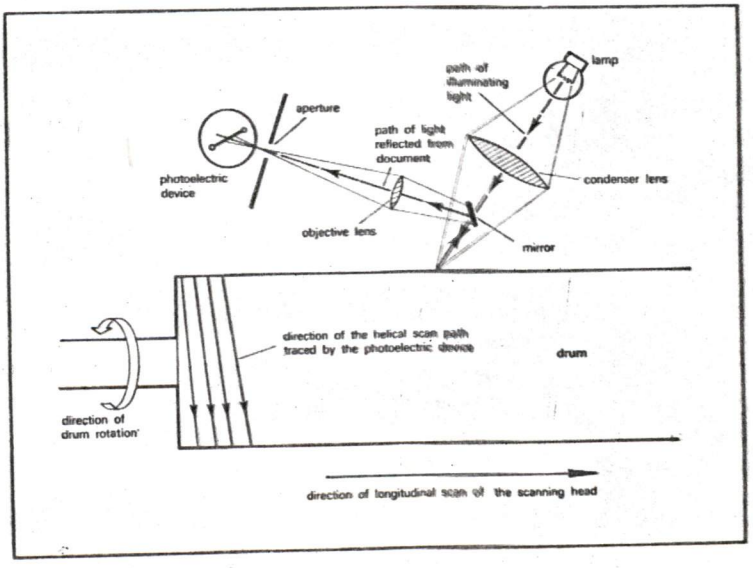
Methods

There are three types of facsimile telegraphy:

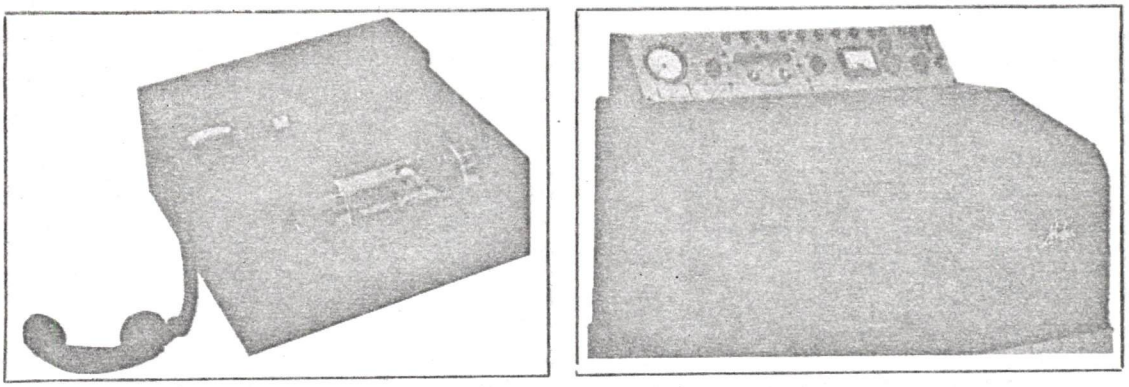
Photo telegraphy This is the transmission of monochrome or colour photographs, and the reproduction of the photographs to as near as possible to correct tone range and, in the case of colour, the hues. Photo telegraphy is used extensively by the newspaper offices for the transmission of news photographs. An analogue method of transmission is employed.

Office documents In this case the reproduction has a very limited tone range near the two extremes of black and white. The meteorological office uses this method for sending weather maps, and many private firms use it for the transmission of office documents. Because only the two extremes of black and white are used a binary or digital method of transmission may be employed.

High speed for newspapers Like document facsimile, only the two extremes of black and white are used but, because of the high resolution of the system, about 600 to 1,000 lines per inch, the minute dot structure



1 Principle of the facsimile scanner; the light spot follows a helical path along the drum and the reflected ray falls on a photoelectric device which converts it to an electrical signal



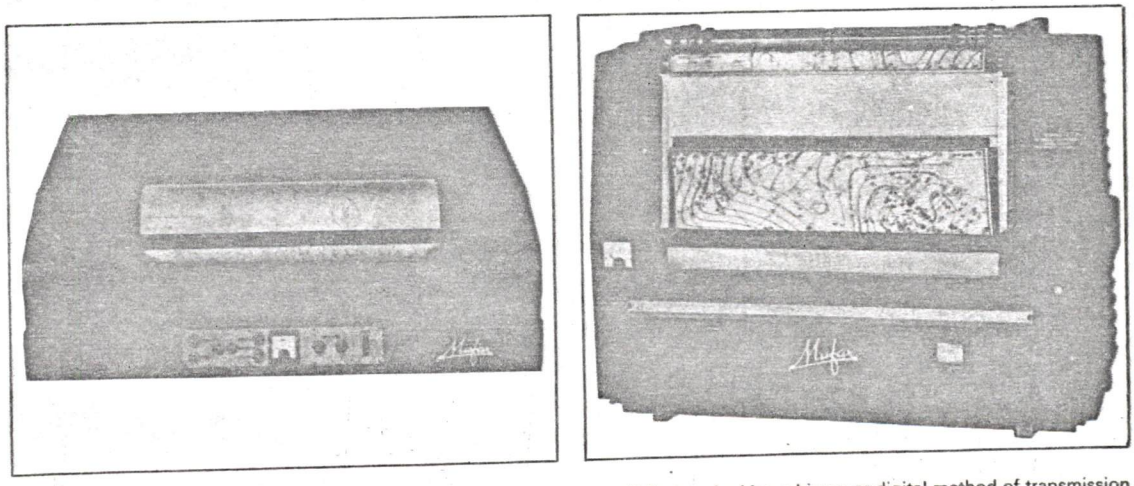
2 Picture transmitters operate on an analogue system to give the full tone range. Scanning rates are up to 100 lines/in at drum speeds of 60 or 120 rev/min. The recorder can be fully automatic to include processing of the photographic paper

of the newspaper photographs is preserved. This enables both the print and photographs to be reproduced faithfully. The system is used by newspapers to transmit a whole page of a newspaper for the production of a printing master at regional printing offices of the national newspapers. Again a binary or digital method of transmission may be used.

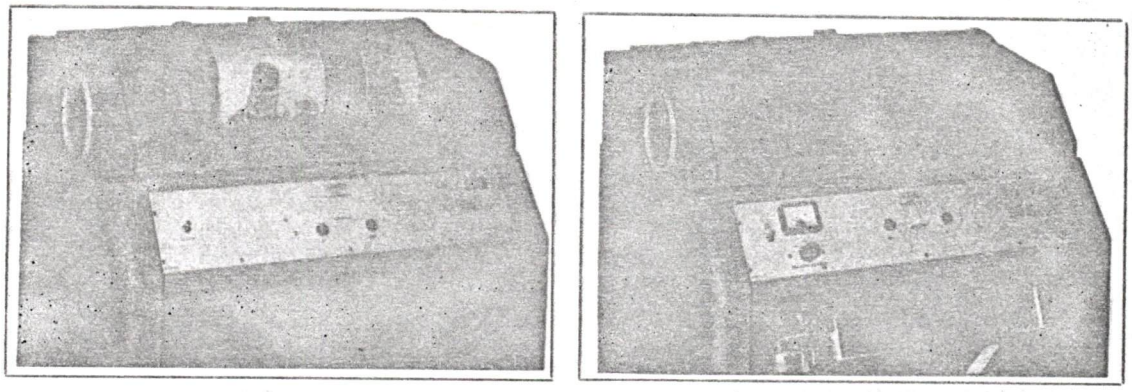
Principle of operation

The general principle of the facsimile transmitter is to scan the original document in a series of lines with a beam of light, and the light reflected from the document is made to act on a photoelectric device (Outline 13). The output from the photoelectric device produces an electric current which for photo telegraphy is proportional to the intensity of the light reflected from each section of the picture. An outline diagram of a typical facsimile machine scanning system is shown in **1**. If only a limited tone range is required, as in document facsimile, then the transmitted signal need not be proportional to the reflected light, but in the limit need only have two states equivalent to black and white. At the receiver a recording blank is scanned in synchronism with, and in the same manner as, the original picture at the transmitter but here the received current causes a marking device to mark the recording blank.

The form of the signal from the photoelectric scanning device is not suitable for transmission over the normal telephone network, and a process of modulation is therefore introduced. This changes the transmitted signal into a form which can be carried over the telephone network without suffering undue impairment or interfering with the functioning of the telephone network. A typical transmission time for an A4 size document using a documentary facsimile machine to CCITT (International Telegraph and Telephone Consultative Committee) standards and an ordinary public switched telephone line is 6 minutes.



3 For office documents and weather charts which require only extremes of black and white, a binary or digital method of transmission is used. The recorders are fully automatic and start on a signal from the transmitter



4 As for documents, a digital system is used for newspapers but the high resolution of the system allows much higher speeds—about 600 or 1,000 lines/in. The receiver produces a negative for immediate printing down on offset or letterpress plates

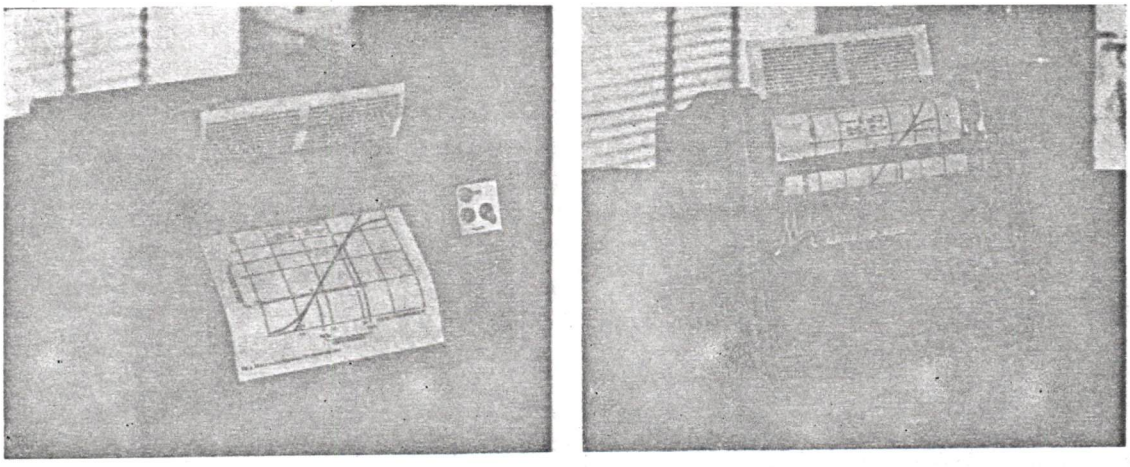
Methods of recording the received copy

In the case of photo telegraphy and high-speed facsimile for newpapers the marking device is a light source whose intensity is controlled by the incoming facsimile signal. The light is then focused by an optical system to produce the correct spot size on the surface of the recording blank. This blank may take the form of either photographic paper or film, and by selection at the receiver either a positive or negative may be produced from a transmitted positive picture. Because the recording blank is sensitive to light, the scan exposure is carried out in total darkness by the use of a special cassette. This allows the machine itself to be operated in normal light. At the end of the transmission the cassette is closed and removed from the machine. The film or paper is removed from the cassette in a photographic darkroom and then processed in the normal way. There are available completely automatic machines which, at the end of the transmission, processes the film or paper automatically; this allows the complete operation to be carried out in normal light.

The methods of recording used for office document facsimile vary widely in implementation, running cost and performance. Four of the more common methods are listed below with their approximate running costs.

Ink wheel recording This gives a sharp copy with only two tones, one being that of the blank paper, the other that of the ink. Normal good quality office paper may be used as the recording blank so that the running cost is low, about 0·25*d* for an A4 size sheet. The system is good for transmitting clean two-tone documents but is less satisfactory for smudged documents or ones containing both typescript and photographs.

Percussion printing This again gives a sharp copy, with the possibility



5 The Courier transmitter will take documents up to 8½in by 14in and starts automatically by pushing the document into a slot. Transmission is over a public telephone line or network. Handwritten, typed sheets, drawings or continuous matter can be transmitted

of producing multiple copies, typically three, and a range of about eight to ten tones. The running cost is reasonable at about 0·5*d* for an A4 size sheet. This cost is based on the re-use of a high quality carbon paper for about 40 recordings. The operation of the system is generally somewhat noisy and is therefore unsuitable in certain applications.

Electrolytic recording This uses a special paper which is impregnated with a solution such that when the marking stylus causes a current to flow between the stylus tip and the paper an electro-chemical reaction takes place at the point of contact. This reaction causes an ink well to form and the paper in the vicinity of the stylus tip changes colour. The paper requires careful storage to prevent the drying out of the electrolytic solution. Once a roll is removed from its storage pack it must be used within six months. The quality of the recording is slightly blurred, but in general this is not unacceptable. The approximate cost for an A4 size sheet is 2·5*d*. The storage life of a recording before severe degradation takes place is about three to five years, and some papers can cause reaction with adjacent documents.

Voltage sensitive paper This is a special paper which consists of a white top coating and a black base. The paper is conductive and when a marking voltage is present between the stylus and the paper the white top coating is burnt away by spark erosion to expose the black base material. This method gives a good sharp copy and a range of about 10 to 12 tones. The cost for an A4 size sheet is at present in the range of 8*d* to 10*d*. The small burnt pieces of paper produced by the spark erosion process have to be removed by an extractor fan and filter assembly which requires regular cleaning. There is also some smell due to the burnt material. The paper is somewhat pressure sensitive and recorded copies need to be handled with reasonable care.

Current and future developments

As you have been reading this article you have probably been unaware that your eyes under the control of your brain have only scanned the text, not the margins or line spaces which contain no information. The facsimile machine has no brain, and, as such, scans the whole document which contains a great amount of redundant information all of which has to be transmitted in the simple facsimile system. Because a telephone circuit can only transmit information at a certain maximum rate, some current developments are aimed at reducing the amount of redundancy transmitted in order to shorten the transmission time required and hence the cost of the telephone call. The greater complexity of the data compression facsimile equipment considerably increases its cost, and ultimately a cost benefit study is required to assess the viability of any such system.

The choice of data compression system type will depend upon the types of document to be transmitted, eg typescript, maps, drawings or combinations of these. This is because simple data compression systems may be optimized for any one type of document but not all types. The more complex data compression systems incorporate several encoding algorithms or other methods of removing the redundancy, and the optimum one is chosen for any given portion of the scan. A new problem arising with these systems caused by the removal of the natural redundancy is the increased effect that transmission errors have on the received copy. This may be overcome by using error correction codes but these require the addition of redundancy and so at least partly negate the gains made.

The other areas of development, especially for low cost document facsimile, are the reduction or removal of the number of precision mechanical parts required in the machines, and improved and cheaper methods of reproduction at the receiver. Only if these developments come to fruition and reduce the capital and running cost of facsimile systems will they move from the specialist market into the mass market. For about 125 years facsimile systems have promised so much but have as yet failed to reach the mass market; perhaps the next five years will be a different story.

Acknowledgment

Grateful acknowledgment is made to Muirhead Ltd for the illustrations of commercial equipment.

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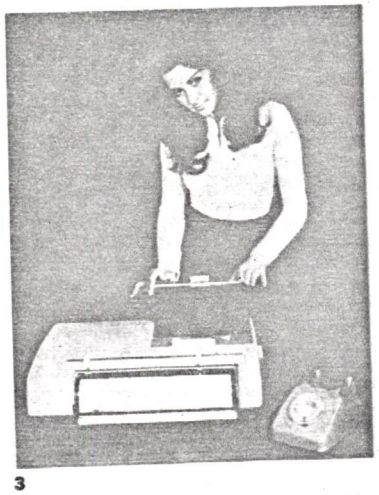
To detach this Engineering Outline for filing, lay the journal on a flat surface, press the binding back on each side of the Outline, take a firm hold on the top corner and pull steadily.

week. Within a few months this office expects to be handling reservations at the rate of 300,000 a year. By the end of 1970 reservation offices will have been opened in Birmingham, Glasgow and Manchester. It is likely that by 1971 a number of national systems will be operating in Europe as part of a world-wide reservation service. Here is yet another example in which the vast storage capacity and fast information retrieval time of the computer can be used to advantage in this teeming world of ours.

Documents by telephone

A speedy method of transmitting documents through an ordinary telephone set, widely used by government and industry in the United States, is now available in the UK. Sole marketing rights for the dexl facsimile transmitter/receiver in the UK and Europe have been secured by University Computing Company, Chandler's Ford, under an agreement with the inventors, Graphic Sciences Inc. Danbury, Conn.

The dexl, see picture, is similar in appearance to other machines of the type. The document to be transmitted is loaded on to the surface of a drum which rotates in front of a travelling photo-electric reading head. The signals are then used to amplitude modulate a 2 kHz tone which is



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transmitted over the telephone circuit. The received signal at the terminal is decoded and applied to a stylus which burns, by spark discharge, an image on specially prepared paper. There is no fading of the reproduced document with prolonged exposure to light.

In operation, the machine is coupled to the telephone hand set, which is mated to a loudspeaker/microphone assembly in a compartment at the back. There are three controls: transmit, stop, receive. The operator first calls the party at the receiving end to establish readiness and then places the handset in the machine. There is a 6-second delay after pressing the transmit button to ensure that both machines are switched on. Quality of transmission is said to be good and the machine has no difficulty in reading coloured print.

Documents up to 9 in by 14 in can be handled by dexl, and the machine can read characters as small as 8pt as on this page. It has also successfully handled Japanese script (over a New York-Tokyo satellite circuit) and engineering drawings. The Japanese example shows the long-range capability of the dexl. It can be used anywhere in range of a telephone, and is in fact frequently employed by the US Army in communications between field stations in Viet Nam and Washington.

In the UK the equipment is available on a rental basis at £37 5*s* a month inclusive of maintenance, for a 5-year lease. Sale price is £1,450 per unit. It must, however, be remembered that the unit does not require a permanent telephone circuit of its own, and, since it weighs only 45 lb, is portable between office locations as required.

Enquiry Card: circle No. 193

The Canberra is 21

This week saw the first anniversary of the first flight of the Canberra, the first jet bomber to enter service with the RAF, and one of the most successful military aircraft to be built in the UK. Friday, 13 May 1949 was no unlucky day for a first flight that heralded production of nearly 1,400 aircraft, and sales worth £135M.

The Canberra was the first aircraft to be wholly designed and built by the English Electric Company, whose involvement in aviation up to then had been sub-contract assembly. It says much for the advance in aircraft design and the growing complexity of electronic systems in the intervening years that no company could today embark on the construction of a sophisticated front-line military aircraft from such modest beginnings.

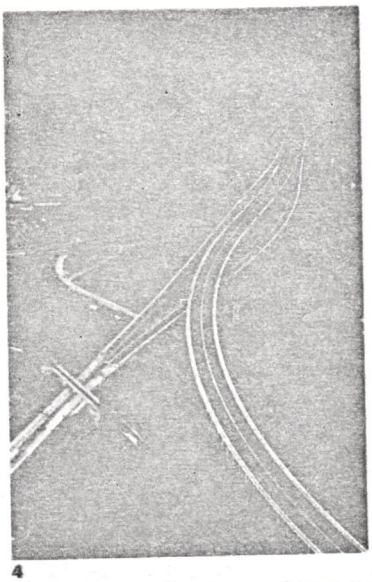
Production of the Canberra was accelerated by the Korean war, and in addition to the English Electric line at Preston, production lines were set up at A V Roe, Handley Page, and Short Brothers & Harland. But the most significant additional production lines were abroad. In Australia, 48 aircraft were built under licence for the RAAF—versions of the B2 and B6 models in service with the RAF. In the United States, however, over 400 aircraft were built, modified from the original design as the B-57, by the Glenn L Martin Company. Many of these American-built aircraft are in regular service today in Viet Nam.

Closing the motorway gap

A continuous motorway route from Ross on Wye to Carnforth, just north of Lancaster came into being today with the official opening of the northern extension of the M5 to link with the M6 at Ray Hall on the northern outskirts of Birmingham. Central feature of the scheme is the triangular motorway junction at Ray Hall, the third exit of which will eventually continue down to the M1 near Rugby.

A 2·8 mile section built by Taylor Woodrow Construction Ltd, from the M6 into the Ray Hall junction, is on viaduct for nearly two-thirds of its length, carrying traffic over existing roads, railways and an industrial estate. The contract was one of 11 placed with various contractors. Sir Owen Williams & Partners were the consulting engineers.

The viaduct totals just over 9,000 ft and is in three sections. At Bescot and Ray Hall the viaducts comprise piled foundations supporting 4 ft or 5 ft diameter reinforced concrete columns supporting reinforced concrete cross beams, 108 ft long. The columns range in height between 13 and 55 ft. Ten structural 'I' beams, 3 ft by 1 ft,



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span between adjacent cross beams to support the 9 in thick reinforced deck. Precast units laid along the edge of the deck act as a combined parapet and vehicle crash barrier.

At Hough the viaduct is of reinforced concrete construction for half the motorway width with an earth embankment for the remaining half. A full width embankment could not be built because of the proximity of gas storage tanks. The 1,200 ft long viaduct comprises reinforced concrete deck slabs 130 ft long supported at each end by drop beams supported in turn on 2½ ft diameter corbelled columns on piled foundations. An 8 ft high in-situ concrete wall forms a parapet and vehicle crash barrier.

Apollo probable failure identified

Most likely cause of the explosion aboard Apollo 13 on its way to the Moon last month was an electrical failure in the No 2 oxygen tank of the service module, according to Dr George Low, NASA deputy administrator. Probable chain of events was a short circuit in the fan motor or its wiring followed by combustion and a pressure build up leading to rupture.

The tanks containing the liquid oxygen and hydrogen supplies for the fuel cells and life-support systems contain electrically driven stirrers to ensure phase separation. The tanks also contain heaters and electrical probes for measuring temperature and contents. Neither of these devices carry substantial currents, but the supply to the stirrers is at 115V. Insulation on the stirrer wires and possibly the wires and the aluminium components of the tanks are regarded as potential sources of combustion, but analysis of telemetry information from the spacecraft and photographs taken by the crew is not yet complete. The investigating committee are expected to report at the end of the month.

As a result of the curtailment of Apollo 13, the next mission, still officially in October may be rerouted to Fra Mauro. Apollo 14 was originally scheduled to visit the Littrow area on the fringe of the Sea of Serenity, but Apollo 13's target area is considered the more interesting selenologically.

Magnavox Systems' new two-speed Magnafax 860 facsimile unit offers the user option of 3 min or 6 min transmission for full-page documents through a coupling to the telephone. According to company spokesman, unit can cut telephone costs for high-volume users by as much as 50 percent.

Flexible Fax

A NEW, low-cost, high-speed facsimile telecommunications unit can cut telephone costs by as much as ½, according to Magnavox Systems, Inc., a subsidiary of The Magnavox Company. The new unit, Magnafax 860, is a two-speed model which offers the user the option of a 3 min or 6 min transmission for full-page documents (drawings, proofs, financial and priority reports, photographs) through a coupling to the telephone.

The new unit does not require a skilled operator and provides error-free graphic communication. The operator can select either speed, depending on volume, distance and speed desired. The two-speed model offers a significant reduction in both telephone line charges and operator time while operating in the 3-min setting, and the 6-min mode provides improved resolution and picture quality. In addition, the 6-min setting permits the Magnafax 860 to speak to a wide number of facsimile devices installed in this country.

The new Model 860 can send to or receive from the majority of facsimile units utilizing the Direct Dial Telephone Network including Magnafax 850, its companion unit introduced in mid-1968. Telecopier I(R), Telecopier II(R), and the Magnafax Militarized Unit AN-GXC-7. Compatibility among facsimile devices adds a wide range of uses because of a growing demand for exchange of graphic material between independent business concerns (purchaser/vendor, agency/client publisher/printer).

The higher speed offered by the Magnafax 860 makes it competitive with Teletype terminals. Facsimile's inherent features offer benefits beyond Teletype equipment because it does not require a skilled operator, and provides document integrity because there is no need to convert and re-format a document prior to transmission. Magnafax units insure privacy of confidential documents, and offer means to transmit graphic illustrations.

Unattended transmission and reception is possible during or after business hours. The Magnafax 860 is coupled to the Bell System Data Access Coupler. This increased automation and capacity to create multiple copies at the receiving end permits economy in off-hour telephone use.

Vinyl-to-Metal Bonding

A SYNTHETIC resin-based adhesive, specifically designed for laminating unbacked vinyl films to aluminum, steel, galvanized steel, and other metal bases, has been developed by the Chemical Division of USM Corp. The new adhesive will be marketed under the tradename Bostik 7242C.

According to E. P. Stokes, Bostik 7242C exhibits greatly improved performance characteristics over existing vinyl-to-metal adhesive types. "In all respects," said Stokes, "7242C will match or outperform any adhesive now used in the metal laminating market." He explained that USM had improved product performance in three areas which are particularly critical to the metal laminator, i.e., activation, flammability, and mileage.

"First of all," he stated, "the vinyl-to-metal adhesives now available must be activated and cured at temperatures of 390 F and above; 7242C, on the other hand, can be activated and cured at 350 F. Also, these same adhesives are highly flammable, whereas 7242C has an extremely high flash point, 153 F (T.O.C.). And in terms of mileage and profitability, laminators can expect to obtain from 100 to 200 more square feet of coverage with a gallon of Bostik 7242C than with any other available vinyl-to-metal adhesive, for a considerable cost savings." He added that these mileage figures would, of course, vary depending on the particular operation involved.

In addition to the improved product characteristics, Bostik 7242C, a two-part thermosetting system, also provides excellent hot green strength which results in a strong, heat and weather resistant bond that withstands drawing, bending, punching, and other metal-forming operations. Of particular interest to metal laminators is the excellent flexibility and resistance to plasticizer migration which 7242C imparts, as well as its good non-staining properties. Furthermore, the system is said to be easy to handle and the adhesive may be applied by either roll or curtain coater.

Nuclear-Powered Car

A POLLUTION - FREE experimental space power system—with potential application as an automobile engine—has undergone successful endurance demonstration (1000 hr) testing at the Aerojet-General Corp.

ORACLE (acronym for Organic RAnkine cyCLE) is a modification of the Rankine cycle used in steam engines. It uses a single organic working fluid in a closed-cycle system to convert nuclear or isotopic energy into electricity for a wide range of space, undersea, and earth applications. The system is also adaptable for operation with solar or chemical heat sources.

The current ORACLE was originally designed to convert isotope power into electrical energy to handle the 3- to 6-kw power needs of a proposed U. S. Air Force Manned Orbital Laboratory (MOL). A 12-kw ORACLE system was designed earlier by Aerojet and demonstration testing confirmed the capability for larger power output from compact engines by appropriate adjustment of exhaust pressure.

Richard W. Barret, Aerojet program manager said "Based on the . . . experience gained since 1966 with these two ORACLE units, we are now studying [the possibilities of] 50- to 150-hp pollution-free automotive propulsion packages."

Net electrical power output of the advanced system exceeded the 6-kw design during the recent tests and the ORACLE's efficiency reached the predicted 17-percent level, reports Barret.

The ORACLE is under development for the AEC's Space Nuclear Systems by Aerojet's Nuclear Systems Co., Azusa, Calif.

Electronic Color Separation with Laser Light Sources

DIETRICH MEYERHOFER, MEMBER, IEEE, A. WILLIAM STEPHENS, AND JOHN J. WALSH

Abstract—Improvements in electronic color scanners appear possible by replacing current light sources with coherent radiation from lasers with much higher radiance. This allows higher speeds of operation (subject to mechanical constraints), greater enlargement capability, and the use of lower sensitivity recording films, or other media. These possibilities were verified experimentally by replacing the reading light source in an RCA color scanner by a combination of argon-ion and He–Ne lasers and the writing light source with an argon-ion laser. The light intensity of the writing light source was modulated by an electrooptic modulator driven from the signal output of the color-correction computer. When this signal was pulsed electronically, it was further possible to directly generate a screened halftone image on the scanner. This is due to the fact that a laser can be operated with a Gaussian spatial energy density distribution. When such a distribution is focused onto a high gamma film, dots are produced whose size is related uniquely to the intensity of the light pulse.

Introduction

IN PRINTING multicolor images, it is necessary to prepare several printing plates, one for each of the printing inks used. These printing plates are now generally produced photomechanically from films containing the images that are to be reproduced in a particular color. These films, or color separations, have in the past been produced photographically by imaging the multicolor original through appropriate filters [1].

Color separation can also be performed photoelectrically on color scanners. These scanners are high-quality facsimile machines, which include provision for separating the light from the scanned original into the required spectral regions. They also include a computer for making corrections to the filtered images to allow for the imperfections of the printing inks. This is analogous to the corrections made in photographic color separating by masking procedures.

In this paper we will be concerned with the capabilities of speed and resolution of facsimile scanners, as determined by the existing light sources used in the scanning and writing parts of such scanners. We discuss the potential of using laser light sources for these functions. While the discussion in this paper is concerned with electronic color scanners, the calculations and results are generally applicable to facsimile equipment.

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The authors are with RCA Laboratories, Princeton, N. J. 08540.

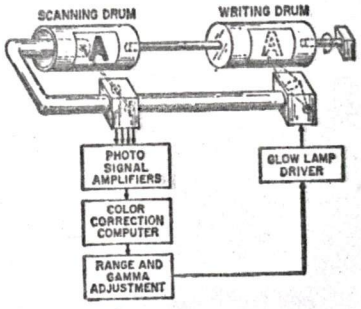

Fig. 1. RCA color scanner.

Color Scanner

An RCA color scanner (Model 70/8802), shown in Fig. 1, was used in the experiments to be described. The original transparency is mounted on a transparent scanning cylinder. (The scanner can be modified to scan reflective copy as well.) This cylinder is locked to the writing cylinder on which the unexposed film is mounted. The two rotate together at constant speed. The scanning and writing heads are also locked together and move at a fixed velocity, parallel to the cylinder axes. The resulting spiral lines are spaced at 50-μm (0.002-inch) intervals. (A scan with half the pitch and linewidth is also available but was not used in these experiments.)

The light passed through the transparency is separated into three spectral components by blue, green, and red filters in the scanning head. Three photomultipliers detect the signals. A point in the original transparency that contains yellow, and must therefore be printed with yellow ink, does not transmit any blue light through the blue filter. Points without yellow do transmit blue light, causing the photomultiplier to produce a signal. This signal is therefore used to make a negative of this yellow separation. Similarly, the green filter produces the magenta separation signal and the red filter, the cyan separation. Positives of the separations can also be made by reversing the electronic signal later in the processing. The signals are amplified and logarithms taken, since optical density is a more appropriate system for further processing than percent transmission.

The color-correction circuitry corrects one color signal at a time for imperfections in the printing inks and the original transparencies. This is done by adding or subtracting appropriate amounts and combinations of the other color signals, as is done in conventional color separa-

TABLE I
RADIANCE OF THE TUNGSTEN LAMP IN THE THREE SPECTRAL REGIONS

Filter	Red	Green	Blue	
Center wavelength, λ	650	550	450	nm
Peak transmission	1.0	0.2	0.2	
Bandwidth, $\Delta\lambda$	100	60	60	nm
Spectral radiance, $W/\Delta\lambda$	730	400	180	$W \cdot m^2 \cdot nm \cdot sr$
Radiance, W	73 000	4800	2160	$W \cdot m^2 \cdot sr$
Power on $(25\ \mu m)^2$	9	0.6	0.3	μW
Measured power through smallest aperture	0.8	0.09	0.02	μW

tion by masking. The corrected color signal is adjusted in range and gamma to take account of the transfer characteristics of the film, printing plate, and printing process, and to optimize the final result. The final density is again converted to a linear signal and, after amplification, is applied to the light source in the scanning head.

SCANNING LIGHT SOURCE

The scanning light source used in the RCA color scanner is a 15-watt tungsten lamp of about 3000°K color temperature. The radiance of this source (i.e., the power emitted per unit area of the source into a unit solid angle) in a given spectral region ($\Delta\lambda$) is calculated from the Planck's black body radiation formula

$$W(\Delta\lambda) = \frac{1}{\pi}\int_{\Delta\lambda} \frac{\epsilon 3.7 \times 10^{-16}\lambda^{-5}\, d\lambda}{\exp(1.4 \times 10^{-2}/\lambda T) - 1} \text{ W/m}^2\cdot\text{sr} \quad (1)$$

where λ is the light wavelength (in meters) and T the absolute temperature. The emissivity ϵ is approximately 0.4. The radiation is separated by filters and mirrors into the three spectral regions required. The filters are similar to those used in conventional color separation [2]. Their spectral transmission is shown in Fig. 2. The approximate center wavelength, peak transmission, and spectral width is shown in Table I. These values are used to calculate the spectral radiance ($W/\Delta\lambda$) of the source from (1), as transmitted by the three filters (fourth line of Table I). Also shown is the maximum amount of light that can be focused into an area $(25\ \mu m)^2$ by an $f/2$ lens (0.2 sr). This is the area that is necessary for a maximum resolution consistent with the fine scan.

The powers measured at the cathodes of the photomultipliers are shown in the last line of Table I. The absolute values are accurate to a factor of 2. They are 5 to 10 times smaller than the values calculated due to additional losses in the optical system and a higher effective f number.

The photomultipliers used to detect the signals are type VFS950F (Fernseh GmbH, Darmstadt, Germany). They are 9-stage tubes with an $S11$-like Cs–Sb cathode similar to the 6199 tube. The radiant sensitivity averages 0.3×10^{-2}, 2.4×10^{-2}, and 4×10^{-2} A/W, in the red, green, and blue spectral regions of Table I, respectively. This means that the spectral responses of the tungsten lamp–

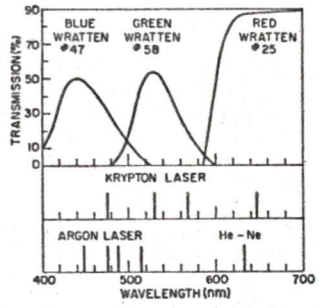

Fig. 2. Spectral transmission of typical filters used in color separation. Also shown are wavelengths of krypton ion laser and of combination of argon ion and He–Ne lasers.

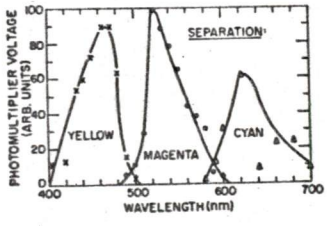

Fig. 3. Combined spectral response of tungsten light source, filters, and photomultipliers. Output voltages of three photomultipliers are plotted versus wavelength of tungsten light source (selected by 5-nm-wide filters).

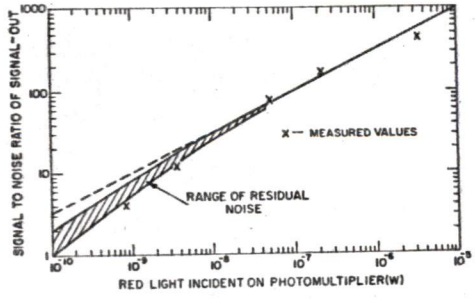

Fig. 4. Calculated SNR for $S11$ cathode. Nominal range of residual noise is shaded.

filter combination and that of the photomultipliers approximately compensated each other. The combined response is shown in Fig. 3 where the output voltage of the photomultipliers as function of incident wavelength is plotted. The wavelengths were selected by interference filters of a 5-nm bandwidth placed in the film plane.

The noise response is calculated from a combination of shot noise and residual noise of the tube as

$$I_n = [i_e + (2e)^{1/2}(I_c)^{1/2}](\Delta f)^{1/2} \qquad (2)$$

where I_c is the cathode signal current and I_n the rms noise current. The bandwidth Δf is 10^5 Hz for the color scanner. The residual equivalent noise current i_e can vary from an average value of 2×10^{-16} A/Hz$^{1/2}$ to a maximum value of 8×10^{-16} A/Hz$^{1/2}$. When the currents in (2) are converted to incident optical power the signal-to-noise ratio (SNR) I_c/I_n can be calculated. The resulting relationship for the red filter signal is shown in Fig. 4, with the two extreme values of residual noise indicated. The two other signals have lower noise values, which again compensate approximately for the smaller values of light incident. The SNR (incident signal light/rms noise value) was also measured at various levels, and the points are plotted in Fig. 4 for the red signal. The measured values are in satisfactory agreement with the theoretical prediction.

The scanner must be able to measure original transparencies to about a density of 3.0. At that level there will be 8×10^{-10} watts incident on the red photomultiplier for the highest resolution (Table I). This will be detected with an SNR of less than 10, indicating that the lower limit has been reached. In other words, a picture can just be scanned at a resolution approaching 25 μm, with a signal rate of 100 kHz. Higher speeds will only be possible for lower resolution requirements. On the other hand, if color separations are to be made from 35-mm slides, or similar small originals, higher resolution must be used with correspondingly lower speed.

Replacement of the Read Light Source with a Laser Source

To increase the scanning speed over that presently available, a source of increased radiance is required. A higher temperature tungsten source is one possibility, but the tube life quickly reduces to impractically short values with higher temperature. Radiance 10 to 100 times higher can be obtained with electric arc lamps and high-pressure mercury arc lamps. Alternatively, lasers with coherent light of essentially infinite radiance can be used. They are now becoming available with power supplies similar to those required for arc lamps and with comparable efficiencies. Lasers also have long life and good stability.

A possible disadvantage in the use of lasers as a read light source is the fact that the radiation consists of a number of discrete spectral lines. It is therefore necessary that the dyes used in the color originals absorb at least one of these spectral lines. This will be true for any photographic dyes in transparencies and prints, for any originals printed with printing inks, and for most art work. However, there may be some artists pigments that can not be reproduced, such as certain of the fluorescent colors. This will rarely constitute a limitation in practice.

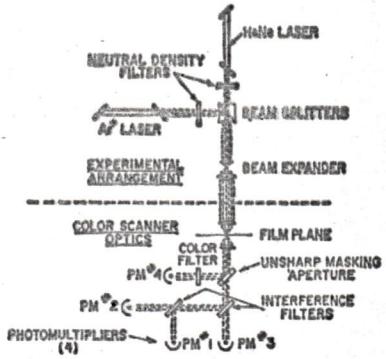

Fig. 5. Experimental arrangement for introducing laser light source into scanning head.

There must, of course, be one laser line in each of the spectral regions into which the color is to be separated. The only single laser which fulfills this requirement is the ionized krypton gas laser with lines at 476, 530, 568, and 647 nm, as indicated in Fig. 2. Alternatively, two lasers can be used, a He–Ne gas laser with radiation at 633 nm, combined with an ionized argon laser with lines at 458, 476, 488, and 514 nm (Fig. 2).

Our experimental tests were made with a combination of the argon and He–Ne lasers. The two beams were combined with a beam splitter and introduced into the RCA color scanner in place of the tungsten lamp and its condensing lens. The experimental arrangement is shown schematically in Fig. 5. Intensities of the lasers were adjusted by the use of neutral density filters and adjustment of the anode current. A beam expander was also incorporated into the system to eliminate misalignment due to vibration between the supports of the lasers and the scanner which were not mounted on the same base. In the experiment, about 1 μW of light was incident on the red photomultiplier, which is the amount required for the maximum usable SNR. The gains of the photomultipliers were adjusted in the usual way to compensate for differences in light levels.

Two sets of color separations were made from the same original transparency, one with the tungsten light source, the other with the arrangement of Fig. 5. The four-color prints produced from the color separation showed slight differences due to the different wavelengths of the reading light. However, these differences can be eliminated by making the appropriate adjustments in the color-correction circuitry.

The smallest lasers generally available produce about 1 mW of coherent light. Allowing for losses in the filters and optics, this means that at least 100 times as much power is available in a focused spot as with the tungsten source.

Writing Light Source

The processed video signal for the separation to be made is amplified and applied to a crater glow lamp. The light is focused onto the recording film in a 25- or 50-μm square spot, depending on the scan used. The glow lamp brightness is linearly dependent on the current over the required three decades of modulation over a frequency range from 0 to 100 kHz. This provides one upper limit to the scanning velocity. Another limit is provided by the luminance of the writing lamp, which is 8.5×10^5 nit at maximum current or approximately 2×10^3 W/m^2·sr in the spectral response region of a panchromatic film. Focused by a $f/2$ lens, this will provide at most 0.3 μW incident on the 25-μm square dot. With an exposure time of 10^{-5} second, only films with an ASA rating of 100 or higher and little reciprocity failure can be exposed. In actual experience, films over ASA 300 are needed. Any increase in scanning speed will require more light or more sensitive films.

As discussed in the previous section, a laser with its high radiance can provide a large increase of light in the focused spot. An electrooptic modulator will be required to provide the necessary modulation. They are capable of higher frequency operation so that the speed of scanning can be increased. In addition, less sensitive recording films can be used if desired by increasing the laser power. Light intensities 10^5 times higher than produced by the glow lamp are feasible. In the present instrument there is the added advantage that the laser used for the reading operation can also be used for the recording step.

To test the feasibility of using a laser for the writing source, we replaced the glow lamp and its optics by a focused beam from a modulated argon-ion laser. The experimental arrangement is shown schematically in Fig. 6. The argon-ion laser is an experimental continuous wave unit built by J. Fendley, of RCA Laboratories [3]. It was usually operated at 488 nm, where up to 100 mW of power is available for fundamental mode operation. After passage through the modulator and the various optical elements, a maximum of about 10 mW could be focused onto the film. A 5× microscope objective was used to form a 50-μm spot on the film. Not all the optical elements are ahown in Fig. 6. Mirrors and relay lenses are used to transport the beam the 11-meter distance from the laser to the scanner.

The modulator is a commercial electrooptic (Pockels) cell. It is driven by the amplified output of the color scanner computer that was previously used to modulate the glow lamp. The linearly polarized laser light is phase modulated by the cell and amplitude modulated by the following analyzer. This results in the following dependence of transmitted light intensity on the voltage V

$$I_t/I_0 = \sin^2 [(\pi/2)(V/V_{1/2})]. \quad (3)$$

$V_{1/2}$ is the half-wave voltage of the modulator, 200 volts in this case. Since this relationship is not linear, corrections must be applied to the signal. In this case, the adjustments

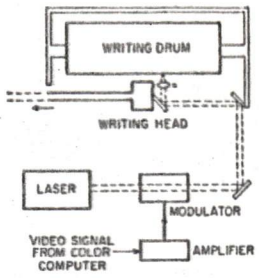

Fig. 6. Experimental arrangement for introducing laser light source into writing head.

available in the scanner computer were used for this purpose.

According to (3), the modulator should have zero transmission at no applied voltage. In our experiment, the smallest value obtained was $I_t(V = 0) = I_0/100$. This was for fundamental TEM_{00} mode operation of the laser, produced by an aperture in the laser cavity. However, the cavity mirrors used caused some distortion in the beam, and an extinction ratio of 1000 should be obtainable from this type of modulator with improved optics. This is enough to produce the density range of about 2.5 required for color separations on the $\gamma = 1$ film.

The exposures were made on Kodak Ortho Scanner film, Type 192. This high-sensitivity film is the one normally used with the scanner. The laser power was varied to find the best level of exposure. To obtain a density of 2.5, about 10 μW of laser power was required on the film. This means that with this equipment exposures could be made on photosensitive surfaces about 1000 times less sensitive.

Formation of Screened Images on the Color Scanner

The output of the conventional scanner is a continuous tone image. One subsequent processing step can be eliminated if screening is performed on the scanner and a halftone image produced. This requires dots of varying sizes to be exposed on the film. Electronic modulation of dot size can best be accomplished by amplitude modulating a light pulse with suitable energy density profile and exposing a high-contrast film.

To perform screening on the color scanner, two requirements must be met. Dots must be produced in locations on the film, such that the desired pattern will be obtained, and the dot size must vary according to the density required. To do this, the continuous tone video signal from the scanner is converted into a chain of amplitude-modulated pulses. These are used to drive the light modulator so that amplitude-modulated light pulses result. By focusing these light pulses onto a very high-contrast film, dots can be produced whose size varies with the amplitude of the pulse. The exact relationship will depend on the spatial distribution of power in the light beam. A desired distribution can be obtained by changing the optics of

the writing head so that the glow lamp is focused into a large spot on the film (of dimensions equal to the screen size) through a variable transmittance aperture. Here the problem arises that there are no high-contrast films available with sufficient sensitivity to be used with the existing lamp in pulse modulation. Again this can be overcome by using a laser as the light source. This had the added advantage that it is very easy to obtain a Gaussian beam profile $[I(r) = I_0 \exp(-r^2/a^2)]$ by operating the laser in the fundamental TEM_{00} mode. The beam profile remains Gaussian even after focusing the beam onto the film. The area of the dot is then proportional to the logarithm of the pulse intensity for nonoverlapping dots. This requires a logarithmic conversion of the video signal before it is applied to the modulator.

In the screening experiment the dots were arranged in a square pattern. The scanner was operated at 500 lines in. (200 lines/cm) so that it is convenient to use a 125-line/screen. By use of the line counter, the modulator was turned on only every fourth scan line. The required 200-μm spacing along a line is produced by a pulse generator. The surface velocity of the drum at the 500-line scanning rate of the scanner is 350 cm/s, so that a pulse repetition rate of 17.5 kH was required. A film strip with markers spaced at the 200-μm intervals was added to the drum and scanned by another light source and photodiode to provide a synchronizing signal for each dot laid down. In this way, a square screen was produced. The shape of the dot on the film depends on the ratio of pulse length to pulse spacing. One observes experimentally that when this ratio is about 1/5 the dots appear to be round.

Most of the tests were made on Kodak Royal Ortho Lith (improved) film. It showed only slightly reduced sensitivity to the 10-μs exposures, as compared to more normal exposures. Tests were also made on another high gamma film with somewhat different properties, Kodak Type 3. It demonstrated very severe reciprocity failure (about 10^{-3} times the sensitivity at a 10-μs exposure) and could not be used.

After some preliminary experiments test patterns were produced in which all pulses were the same size. This allows one to determine the repeatability of the dots. The size of the dots were varied from highlight dots to complete overlap exposure. All the dots produced by the same pulses appeared to be the same size. To obtain a more quantitative determination, microdensitometer traces were made of some of the films. A typical example is shown in Fig. 7. This is a recording trace taken through dots whose intensity is near the high end of the graduation curve. Because of the experimental setup, the densitometer scan does not go through the centers of all the dots, so the width of the dots on the trace is not completely uniform. Nevertheless, the peak densities appear to be fairly constant as required.

After the exposure levels had been determined in this fashion, various runs were made screening a high-quality positive. A reasonably good screened exposure was produced. Part of it is shown enlarged in Fig. 8. The highlight dots are dropped out. The minimum dot size is less than 10 μm, and the maximum dots overlap to produce a white dot about 10 μm in the corners between the exposed dots. This is approximately what is required for a halftone picture. Slight adjustments like changing the gradation and highlight dropout might improve the results further. There is some variation in the spacing of the vertical lines of dots due to movement of the laser relative to the scanner caused by building vibrations. This problem can be eliminated by mounting the laser and modulator on the same frame as the scanner.

The picture in Fig. 8 represents one screened color separation with a horizontal square-dot pattern. In con-

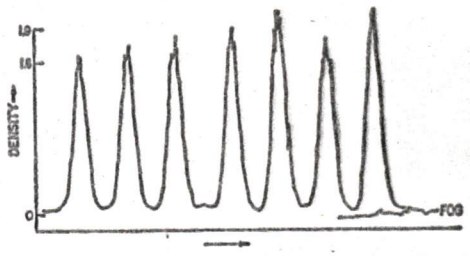

Fig. 7. Microdensitometer trace of halftone screen produced on scanner.

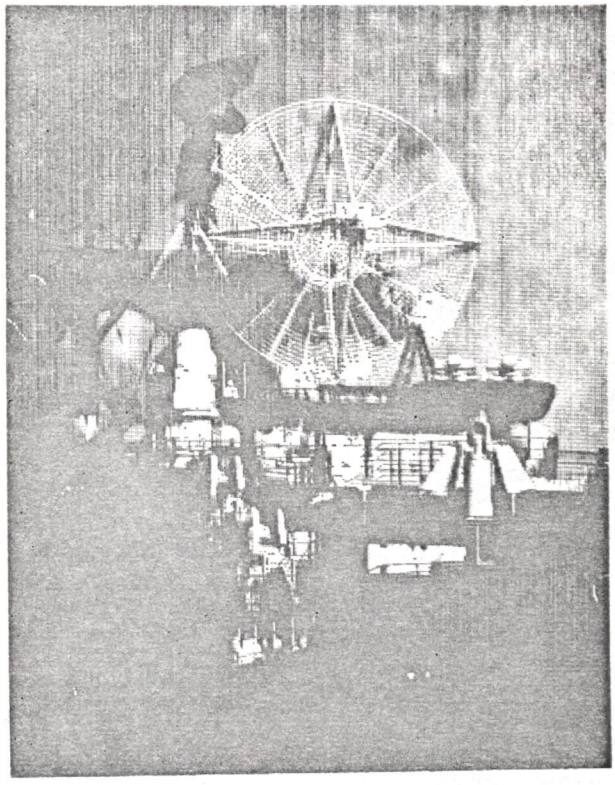

Fig. 8. Enlargement of screened positive made on color scanner with pulse-modulated laser beam. Scanning direction was vertical.

ventional printing use the other color separations have screens (dot patterns) which are rotated relative to one another to minimize interference effects. This rotation is simulated in the electronic screening procedure by changing the frequencies and the relative synchronization of the pulse and line scanning generators.

Acknowledgment

The authors wish to thank J. R. Fendley, Jr., for use of the argon laser and J. C. Hartmann for performing the microdensitometer traces.

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[2] E. Jaffe, E. Brody, F. Preucil, and J. W. White, "Color separation photography for offset lithography," Graphic Arts Technical Foundation, Pittsburgh, Pa., Rept., 1959.
[3] K. G. Hernqvist and J. R. Fendley, Jr., "Construction of long life argon lasers," *IEEE J. Quantum Electronics*, vol. QE-3, pp. 66–72, February 1967.

Dietrich Meyerhofer (M'62) was born in Zurich, Switzerland, on September 19, 1931. He received the bachelor of engineering physics degree from Cornell University, Ithaca, N. Y., in 1954 and the Ph.D. degree in physics from Massachusetts Institute of Technology, Cambridge, in 1958.

Since 1958 he has been a Member of the Technical Staff at RCA Laboratories, Princeton, N. J. His research activities have included the study of electrical properties of semiconductor and insulator, of light emission from semiconductor diodes and lasers, and of Q switching of the CO_2 laser. His present activities are in the area of electronic printing.

A. William Stephens was born in El Paso, Tex., on May 12, 1936. He received the B.S., M.S., and Ph.D. degrees in metallurgical engineering from the University of Arizona, Tempe, in 1962, 1965, and 1968, respectively. He was awarded the Phelps Dodge graduate scholarship in 1963 and a National Defense Education Act scholarship in 1965.

After graduation in 1962 he was employed as a Graduate Research Assistant at the University of Arizona. His graduate research was concerned with crystallographic texture and mechanical anisotropy in metals. He joined RCA Laboratories, Princeton, N. J., in 1966 and has worked in the area of laser micromachining. He is presently engaged in the preparation of nonlinear optic materials by melt growth.

John J. Walsh was born in Philadelphia, Pa., on October 20, 1922. He received the B.S.E.E. degree from Oklahoma State University of Agriculture and Applied Science, Stillwater, in 1949 and the M.S.E.E. degree from the University of Pennsylvania, Philadelphia, in 1956.

He spent 15 years in the gravure printing industry at Triangle Publications, Parade Publications, Publication Corporation, and Detroit Gravure, where he held various engineering and production positions. He was associated with early installations of electronic register control systems and electronic press drives. In 1959 he was responsible for the introduction of the first solid-state register control system in the industry. In 1964 he became associated with the U. S. Agency for International Development and served in Istanbul, Turkey, as a Printing and Electric–Electronic Advisor. In 1966 he joined the newly formed RCA Graphic Systems Division in marketing and product planning. Later, he was associated with the Graphic Systems Applied Research Group at the Sarnoff Laboratories. For the last two years he has been a Consultant in the graphic arts, RCA Laboratories, Princeton, N. J.

Mr. Walsh is a Registered Professional Engineer in the State of Pennsylvania.

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF SCIENCE AND TECHNOLOGY
Washington, D. C. 20506

Advance for use in AMs
of Tuesday, October 26, 1971

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FORMER WHITE HOUSE FELLOW BECOMES ASSISTANT DIRECTOR IN OFFICE OF SCIENCE AND TECHNOLOGY

Washington -- Former White House Fellow Richard E. Balzhiser has been appointed as assistant director of the White House Office of Science and Technology.

Professor Balzhiser, a onetime University of Michigan football standout who won the Western Conference Award of "The Big Ten" for both scholarship and athletic prowess, was chairman of that University's Division of Chemical Engineering.

In the post announced today, Dr. Balzhiser is responsible for the Office of Science and Technology's activities in environment, energy and natural resources.

He will work directly under Dr. Edward E. David, Jr., Science Adviser to the President and Chairman of the Federal Council for Science and Technology, the group which integrates the federal government's interagency research efforts.

The 39-year-old chemical engineer and former White House Fellow worked in the office of Defense Secretary Robert McNamara in 1967-68. He helped organize the Alliance for Civic Action, a group dealing with the application of military resources such as health, transport and other facilities useful in societal problem areas.

He was appointed by the President to the President's Commission on White House Fellows in 1970.

-MORE-

At the University, he was project director for liquid metal research for atomic reactors and space energy systems. Simultaneously, he also served as a Special Assistant to the Vice President for State Relations and Planning at the University of Michigan and was active on numerous academic committees.

An avid athlete, he has coached both amateur hockey and Little League baseball. He does color commentary at Michigan football games when in Ann Arbor.

The Wheaton,Illinois, native has compiled an imposing list of academic publications, including the co-authoring of a textbook in thermodynamics, and several public policy articles relating to technology and government.

Balzhiser and his wife, Christine, maintain their home in Ann Arbor. They have four children.

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— DRAFT —

THE PRESIDENT'S SCIENCE ADVISORY COMMITTEE
EXECUTIVE OFFICE BUILDING
WASHINGTON, D.C. 20506

July 1971

Dear Ed:

Transmitted along with this letter is the final report of the PSAC Panel on Science and Technology Policy. Because the report itself is relatively brief and consists primarily of a tabulation of recommendations with the accompanying descriptive discussions held to the bare minimum, we have not listed these recommendations separately, and I will not comment on them in detail in this letter. Nevertheless, there are a few observations which seem appropriate.

Clearly, President Nixon understands the significance of science and technology not just to the economic strength and growth of the United States but as a cultural bulwark of our contemporary society. Numerous pre- and post-election statements are sufficient proof, as in a more specific sense have been his statements and the actions during our several PSAC meetings with him.

During the February 23 meeting with PSAC, for example, he particularly expressed concern about unemployment among scientists and engineers, not only in a humanitarian sense, but because a major national resource, the professional abilities of these unemployed scientists and engineers, was going to waste.

Yet, unemployment among scientists and engineers results primarily from several coincident actions, by agencies of the U.S. Government (aggravated by the levelling off of requirements for faculty in the educational system), including the decrease in the NASA budget, the decrease in the DOD budget, and the response of the general economy to the fiscal and monetary policies of the federal government in 1969 and early 1970.

It would appear that although the general increase in unemployment was anticipated (perhaps not quite to the extent of the 6% level reached), there was no agency of the federal government which assessed the impact of all of these actions occurring more or less simultaneously on the employment of scientists and engineers and, hence, on anticipatory programs which, to the maximum extent possible, would have capitalized on utilizing the resource so made available by applying it to other program areas where indeed there are great needs for technically educated, experienced personnel.

That this is so should be no surprise to the Science Adviser, OST or PSAC, since they certainly have not been organized to perform this kind of function, and the NSF and Department of Labor data are not prepared for this use.

The failure to anticipate this unemployment problem among scientists and engineers is one example which illustrates in the starkest kind of way the limitations of the present mechanism for discussing, influencing, and making science and technology policy at the federal level. Other examples which illustrate the need are the erratic federal support for Academic Science over the past few years and the growing anti-science, anti-technology feelings within our society.

This PSAC Panel report consists almost entirely of recommendations which if followed would insure the Science & Technology Advisory Mechanism of the President (STAMP)* assuming a much strengthened policy role.

The Panel is, of course, very much aware that, as a matter of fact, you already have begun this kind of expanded role and it views with enthusiasm such examples as the spring pre-budget reviews and the drafting of the initial Annual Report on Science and Technology.

With this report the Panel feels that it has completed its responsibilities and recommends that it be discharged. It also recommends that another panel, under a new chairman, be constituted to deal with specific items of science and technology policy of your choosing. Presumably, this new panel would function under the guidance of the expanded, full-time, professional competence in OST also recommended in this report.

Sincerely,

Patrick E. Haggerty, Chairman
PSAC Science and Technology
Policy Panel

Enclosure
*(STAMP) is comprised of the Science Adviser, OST, PSAC, FCST.

Dr. Edward E. David, Jr.
Science Adviser to the President
The White House
Washington, D.C. 20506

PEH - July 8, 1971

DRAFT

Report

by the

SCIENCE AND TECHNOLOGY POLICY PANEL

of the

PRESIDENT'S SCIENCE ADVISORY COMMITTEE
(PSAC)

July 1971

Patrick Haggerty
Member of PSAC
Panel Chairman

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* STAMP is comprised of the Science Adviser, OST, PSAC and FCST.

PREFACE

This report summarizes the deliberations of the Science and Technology Policy Panel.[1] The Panel was established with the approval of the President in early 1970 by Dr. Lee A. DuBridge, then Science Adviser, under the auspices of the President's Science Advisory Committee (PSAC).

In brief, the Panel was charged with finding improved ways of focusing, supporting and utilizing science and technology in the interest of the nation. The Panel has met monthly -- usually for one day, occasionally for two -- since its inception. During that time an extraordinary breadth of subject matter has been covered, ranging from discussions relating to the development of a rationale for the support of academic science, the relationship of science and technology to our national productivity and economic welfare and to the structure of the Science and Technology Advisory Mechanism of the President (STAMP).[2]

The scope of the subject matter is indicated by Appendix D -- a guide to the more than 2000 pages in nine volumes generated by the Panel itself or reviewed or abstracted in connection with its work. These nine volumes

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[1] See P anel Membership List, Appendix B.

[2] Consisting of the Science Adviser, the President's Science Advisory Committee (PSAC), the Office of Science and Technology (OST), and the Federal Council for Science and Technology (FCST).

are available to the Office of Science and Technology and PSAC to serve as background information for further efforts in the science and technology policy area.

In addition, a collection of statements by individual Panel members enlarging on or criticizing the report itself, or discussing science and technology policy areas which the report itself does not treat, is included as Appendix C.

The Panel realized relatively early in its discussions that just because of the wide variety of subject matter implicit in science and technology policy, it would be able to discuss in detail and arrive at recommendations on only a very few of the items which could justifiably claim attention under that heading. Thus, The Panel concluded that it could be most productive by making recommendations dealing with how to make the PSAM more effective and that is the principal subject matter of this report.

There are four other documents which report preliminary findings either of the Panel or of sub-panels dealing with specific items. All are included in Volume IX described in Appendix C. These four documents are:

1. Report of the PSAC Sub-panel on Academic Science to the PSAC Panel on Science and Technology - Murray Gell-Mann, Sub-Panel Chairman - June 16, 1970.

2. "Progress Report and Observations of Science and Technology Policy Panel," Memorandum from Patrick E. Haggerty, Chairman, to Lee DuBridge, dated June 5, 1970.

3. "Federal Policy for Science and Technology," Interim and Partial Report of August 31, 1970, and the accompanying letter of transmittal dated September 9, 1970, from Patrick E. Haggerty to Dr. Edward David.

4. "On Increasing National Productivity Through Education and Technological Change," Report by Sub-panel on Research and Education - Arthur M. Bueche, Sub-panel chairman, June 18, 1971.

I. THE NEED TO REORIENT AND REFORM THE SCIENCE AND TECHNOLOGY POLICY PROCESS

It is only a very moderate oversimplification to state that Research and Development (R&D) represent the process by which we generate the knowledge encompassed by the term "science and technology." Thus, any discussion about improved ways of focusing, supporting and utilizing science and technology in the interest of the nation soon turns to questions such as the following: For what purposes are given R&D efforts being undertaken? What kinds of Research and Development and how much of it are to be performed? Who should do it? Who is to pay for it?

The Panel found it helpful to its deliberations to divide all research and development into two categories:

1. Exploratory Research; i.e., Research looking to generate or expand knowledge and not aimed at attaining a specific objective. This includes most academic science and basic research.

2. Objective-Seeking Research and Development; i.e., R&D conducted as principal steps toward attaining definite objectives. More than 90% of all our national R&D expenditures fall in this category.

Thus, Category 1, Exploratory Research, is basic to our entire culture. It generates the knowledge in scientific and technological fields which undergirds much of our way of life and based on which we select and conduct the research and development aimed at attainment of objectives. The knowledge so gained may be fundamental to creating and advancing new national goals.

Category 2, Objective-Seeking Research and Development, can be just as fundamental as exploratory research but the motivation is different. For some of the performers exploratory research is an end in itself; for those who support it, exploratory research serves as one of the means to open up new options. However, objective-seeking research and development are always means toward an end.

Obviously, objective-seeking research and development may generate knowledge as fundamental as that generated by exploratory research. Similarly, exploratory research may suggest a completely different approach toward reaching an objective or generate whole new objectives, even though that was not it's motivation. Thus, the division into these two categories is inevitably arbitrary, but it is a useful division and is particularly helpful in establishing the rationale for and mechanisms of federal evaluation and support which are discussed later in this report.

Even this simple classification of all research and development is sufficient to raise significant but difficult questions:

1. How should the United States set major national goals (e.g., in health, environment, defense, space, communications, transportation, etc.)?

2. How can the nation balance these goals so that:

   a. In total they are feasible and do not require resources in excess of our ability or willingness to commit them; and

   b. They are not mutually incompatible; i.e., goals in such areas as transportation or energy with goals involving the environment?

3. How can the Federal Government exercise appropriate leadership to translate these major goals into definitive, specific objectives so that government departments and agencies and the private sector as appropriate can respond acceptably by generating the knowledge, goods, and services which collectively would achieve these major national goals?

4. How can research and development be focused efficiently on these definitive objectives?

5. Are existing institutional arrangements adequate to accomplish 1, 2, and 3? If not, how should they be modified or should new institutions be created?

The Panel's recommendations are restricted to those aspects of 2, 3, 4, and 5 which can be grappled with directly either by STAMP alone or by STAMP in concert with OMB. There is a need for a more coherent mechanism for converting national goals into definitive scientific/technical objectives for responsible agencies, setting technical priorities, and evaluating and assigning R&D resources for accomplishment.

There are principles and procedures which can be adopted by STAMP and OMB that can contribute to answering significant parts of these five questions. The Panel does not pretend that this report treats all of such possibilities extensively. It does believe, however, that adopting the recommendations made in this report would initiate an evolutionary process which will eventually provide solutions to many of the problems posed by these questions.

II. INCREASING THE POLICY EFFECTIVENESS OF THE SCIENCE & TECHNOLOGY ADVISORY MECHANISM OF THE PRESIDENT (STAMP)

It took only a very few meetings for the Panel to conclude that the subject matter implicit in science and technology policy was not only extraordinarily broad but fundamental to the responsibilities of the entire STAMP. It also learned that the professional staff of OST was organized substantially around programmatic areas and indeed, that the STAMP as a whole involved itself primarily in and was organized to handle programmatic matters. As a consequence, only the Science Adviser himself had a continuing responsibility for activities or policies which cut across or were fundamental to all of science and technology. The Panel by summer, 1970, had concluded that the subject matter with which it was dealing was so broad and so fundamental to the entire operations of STAMP that it was inappropriate that it be dealt with primarily by an ad hoc group such as itself. The Panel, in its preliminary and partial report of August 31, 1970,[1] recommended structural and procedural changes in OST to assure that science and technology policy at the federal level would be dealt with on a continuing basis by a full-time, professional staff.

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[1] See Item 3 in the Preface, and Volume IX, as identified and discussed in Appendix D.

The Panel has been meeting monthly for nearly a year since it issued those recommendations, and additional discussion has only strengthened its conviction that the primary focus for science and technology policy should not be in ad hoc groups alone. It makes the following recommendations which agree in principle with its recommendations of last August but differ in detail and emphasis:

1. The STAMP would assume as a primary responsibility the assessment of the overall vitality of science and technology in the United States and for making recommendations thereto. Such an assessment would include evaluating both the appropriateness and adequacy of federally supported research and development for attaining the national objectives at which they are aimed and recommending changes as well as entirely new programs.

2. In addition, on the basis of the opportunities and competencies revealed in this annual assessment, the STAMP would recommend to the President possible new initiatives which might in themselves be expressed as national objectives or which could lead to new national goals. The Panel views the recently announced proposals by the President

for a major and concentrated attack on cancer and for assuring the adequacy of the nation's long-range energy resources as examples of the kind of national objectives which could result from such recommendations.

3. Within the STAMP,the competence for assuming this responsibility should be based on an appropriately organized, full-time, professional staff in the OST. In its August 31, 1970 report, the Panel recommended that this enlarged policy role for the STAMP be begun by establishing a three-man Council of Science and Technology Advisers supplemented by approximately six qualified, full-time professionals. The Panel recommends again that serious consideration be given to the establishment of such a council as a desirable if not essential element to adopting a more policy-oriented role for the STAMP.In the absence of the council, the essential element is the commitment of at least one deputy director supplemented by adequately qualified, professional staff to full-time responsibility in these policy areas. (On a year-in and year-out basis, the Panel still feels that the likelihood of getting three top-quality men of the breadth required for this enlarged role would be higher for a chairman plus two council members than for a director plus deputies.)

4. With basic, professional, full-time competence in the policy area established in OST, PSAC and other panels then can be used effectively to supplement the full-time, professional staff. Panels could be convened to study and recommend specific aspects of science and technology Policy. Qualified individuals, including PSAC members, willing and able to devote from a few weeks to a few months at a time in Washington, could bring strong support in their personal areas of competence. Studies involved in making the assessment recommended under No. 1 could be carried out by a variety of means, including contracts with NAS, NAE, and other profit and not-for-profit organizations, as well as by delegation of appropriate parts of the responsibility to other federal agencies, such as NSF.

III. UPGRADING THE MANAGEMENT PROCESSES OF THE SCIENCE & TECHNOLOGY ADVISORY MECHANISM OF THE PRESIDENT (STAMP)

The Panel recommends that the Science Adviser, as head of STAMP and in fulfilling his responsibilities to the President for assessing the state of federally supported research and development previously recommended,[1] initiate procedures to function as follows:

1. The Science Adviser, in collaboration with OMB, will:

   a. Establish criteria[2] which would be used as a guide, both for their own actions and the other federal agencies whose requests for R&D they would review, in evaluating the appropriateness of and the kind of support provided for exploratory research and objective-seeking research and development.

   b. Establish early in the budget cycle for the succeeding fiscal year the overall level of exploratory research effort which will be supported for that fiscal year by the federal government and project probable levels of effort which will be supported for an additional two years.[3]

   c. Request that each mission agency submit for review its budget for research and development directed to the attainment of its objectives:

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[1] See Recommendation 1, Section II-2.

[2] See Appendix A for proposed criteria.

[3] See Section IV for Panel recommendation for establishing this level of effort.

(1) Stating the objectives of the agency at which research and development are being directed, as well as the schedules for accomplishment; and

(2) Describing the specific research and development programs being conducted to attain these objectives and the budget support levels requested.

d. Assess for the President the adequacy and the appropriateness of Objective Seeking R&D programs (Category 2) for achieving the objectives stated and the coupling of these programs to the other activities of mission-oriented agencies.

e. Assess for the President for both exploratory research and objective-seeking research and development the general adequacy of the organizational structures of the respective agencies for initiating and supervising (and conducting where appropriate) such research and development.

2. The Science Adviser will:

a. Within the envelope of the overall budgetary level for all exploratory research, as agreed upon with OMB, review with each federal agency its exploratory research program. He will coordinate the efforts of the several federal agencies so that the

total expenditures projected for exploratory research would be consistent with the total level previously established. The Science Adviser, as a part of his responsibilities for coordinating the overall effort, will make recommendations to the agencies to assure a well-balanced program including adequate effort in important but not necessarily popular fields. This coordination could make exploratory research, including that aspect of it described as "academic science" reasonably responsive to shifts in national goals and priorities without diluting its creative character.

b. Assess the need for R&D facilities and personnel for the ensuing year as they develop during the reviews; advise the President of major imbalances which appear to be developing, whether these involve shortages or excesses; and make recommendations as to changes in the overall program which might utilize the total technical resources of the nation most effectively.

c. Forecast, to the best of his evolving ability to do so, the probable future of total research and development efforts of the nation over a sufficient span of time to allow him to assess and make recommendations with respect to support programs appropriate to meet these needs for scientists and engineers or for related facilities.

d. Annually, to the best of his ability, assess the level and the adequacy of the privately supported research and development in the nation and make recommendations relating to sustaining and improving the general health of such privately supported research and development.

e. Prepare an annual report on science and technology for the President, the Congress, and the nation in which he details the information and actions resulting from the enlarged policy and action role outlined.[1]

f. Review annually with the President a range of feasible initiatives in science and technology designed to support national objectives or to shape new national goals.

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[1] The Panel in its report of August 31, 1970, recommended that the Science Adviser and OST prepare such an annual report on science and technology, and the first issue is now in preparation. However, to the extent that the Science Adviser implements the recommendations made by the Panel, his annual report will change considerably to reflect the consequences of the science adviser's assessment and recommendations with respect to the overall vitality of science and technology with particular reference to that supported by federal funds.

IV. RECOMMENDED GUIDELINES FOR SUPPORT OF ACADEMIC SCIENCE

1. This Panel recommends that, as a first principle, federal support for that portion of academic science which falls into Category 1, Exploratory Research, be set on the basis of sustaining some specified level of effort. By definition, Exploratory Research is seeking to generate new knowledge and not to attain specified objectives. Inevitably, then support cannot be rationalized on a cause-and-effect basis.

2. It is the Panel's strong conclusion that academic science must know where it stands in its relations with the Federal government. It cannot maintain either quality or vitality under stop-and-go funding. Selection of the proper level of support inevitably always will be subjective; but hopefully, one of the principal intial efforts of the restructured OST recommended will be aimed at analysis, comprehension, and recommendation relating to this level of effort. While OST is being restructured to address this issue more fully to develop a long-term financing formula, the Panel recommends that the present level of effort be adopted as a floor for budgeting purposes.

3. By its very nature, academic science has a very long time constant, and it should not be subjected to unnecessary transients either toward expansion or constraction. Furthermore, the extraordinary diffuseness of the total effort coupled with the mechanisms of university organization and governance make the entire structure of academic science especially vulnerable to unanticipated shifts in level or direction.

Accordingly, the Panel also recommends that OST and OMB, in addition to establishing the level of effort for academic science for the ensuing year, project probable levels of effort to be supported for an additional two years. The Panel suggests that to insure stability and some growth, increases of approximately 5% to 10% in federal support (expressed in $ of the year) for each of the next two years would be desirable.

4. Because it is highly desirable to couple academic science to eventual users of the knowledge generated, it is recommended that a majority of the federal support for academic science come from mission agencies. This will achieve a loose coupling between the mission agency and the exploratory research conducted at the universities and thereby improve the utilization of the new knowledge as a base for the objective-seeking research and development of the mission agencies.

5. Because it is also advantageous for a considerable proportion of academic science to be free of pressures from present applied activities, the Panel also recommends that a considerable proportion

of the federal support about 1/3 for academic science come from the NSF non-mission oriented programs.

6. The Panel is struck by the relatively limited support extended by industry to exploratory research at universities. Undoubtedly, this is because the knowledge generated as a consequence of exploratory research is rarely sufficiently proprietary to give a significant return to the sponsoring private company. Nevertheless, the Panel does believe that loose coupling between users of the knowledge generated and the researcher doing exploratory research significantly increases the utility of the knowledge and shortens the time between discovery and use as a base for objective-seeking research and development. Thus, the Panel recommends that serious consideration be given to Federal support for research and development at colleges and universities aimed at increasing this coupling. *

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*See Item 1, Appendix C.

APPENDIX A

Proposed Criteria for Federal Support of Science and Technology to be Established Mutually by OMB and OST

DEFINITION

Criteria for federal support of science and technology which translates primarily into federal support for research and development represent but a first screen to help us decide whether federal support is warranted. Actual decisions should depend on the specifics of each situation, which include quantitative aspects, value judgements and political balance. No set of criteria can cater, a priori, to such considerations. Analysis, specific value judgements, elements of the specific design, and the implementation of discrete programs, or program evaluations, do not belong in criteria.

A set of criteria by itself cannot yield clear-cut "yes" or "no" answers to the majority of specific situations. However, criteria can provide the framework within which the specifics of any given issue can be rationally discussed. Criteria cannot be expected to replace decision making.

Hence, Criteria should:

(a) assist in providing for a more consistent approach to the support of Science, Technology, and hence, Research and Development, among agencies and programs,

(b) make the decision-making process more rational, orderly, and traceable,

(c) assist in identifying alternative courses of action, and

(d) uncover those factors which decision makers consider relevant and important.

RATIONALE FOR CATEGORIZATION

Conventionally in the U. S. A. scientific/technical activities are categorized as (1) Basic Research, (2) Applied Research and (3) Engineering, based on the nature of the activity. Basic research is not ordinarily related to any specific goal. It is, however, the wellspring of knowledge upon which practically everything else depends for ultimate replenishment. Applied Research is still research in the true sense of the word in that it develops essentially new approaches and procedures. But it differs from basic research in that it is goal-oriented. In this phase of the work detailed prediction as to cost is not yet practicable. Finally, engineering leads to the finished product and the emphasis has to be placed on feasibility, reliability, and also cost-effectiveness. This phase starts when a procedure or product has been proved out in principle, but when the

questions mentioned in the previous sentences are still open. It is almost needless to say that there are no sharp lines of division between basic research, applied research and engineering. However, the above statements may serve as reasonably reliable distinguishing marks.

Orthogonal to the categorization of scientific activities by their nature, is the categorization by the motivation for the activity. Examples of such motivation are (1) The attainment of National goals, (2) The attainment of industrial or private goals, (3) Development of Scientific/Technical Manpower resources (training & education), and (4) Knowledge for the purpose of satisfying man's curiosity or other spiritual demands.

The financing or supporting of scientific/technical activities is strongly dependent on the motivation of the user. Hence, the establishment of criteria for the support of science and technology can be based better on the motivation for, rather than on the nature of scientific/technical activities.

Therefore, the Major Categories and the Guidelines that follow are based on the motivation for, rather than on the nature of scientific/technical activities.

MAJOR CATEGORIES

1. Exploratory Research; i.e., Research looking to generate or expand knowledge and not aimed at attaining a specific objective. This includes most academic science and basic research conducted within or without the Government.

2. Objective-Seeking Research and Development; i.e., R&D conducted as principal steps toward attaining definite objectives. More than 90% of all our national R&D expenditures fall in this category.

GUIDELINES

I. Exploratory research generates the scientific knowledge which is basic to our entire culture. The knowledge generated is so basic to the welfare of our entire society that the federal government quite properly must assume the principal responsibility for its support. Exploratory research conducted at universities has, as a principal purpose in addition to the generation of new knowledge, the training of scientists and engineers, and this total activity has been customarily labeled "academic science." Academic Science is the principal component of our national exploratory research effort. The magnitude, nature, and mix of this support

must be determined with due consideration for the needs of the operating agencies and within the guidelines and review mechanisms as provided by the STAMP, in cooperation with OMB, as appropriate.[1]

II. When there is a requirement to meet certain aspects of the welfare of the U.S., such as its defense needs; or the overall prestige of the U.S. is involved (e.g., space), and the government is the principal or only user; the responsibility for the R&D seeking to meet those needs, (including advancing the necessary technology and establishing possible ranges of performance and their relationship to cost) rests with the federal government, and it should bear substantially all costs involved.

III. While the Federal government should refrain from the support of R&D and technology that fall primarily in the private sector, there are certain exceptions. For example, the federal government should consider support for early R&D in areas which, although useful to fulfill some federal missions, have their primary utility in the private sector, provided:

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[1] See Section IV for the Panel recommendations on ~~these~~ guidelines and review mechanisms.

1. The results of the R&D are likely to have major beneficial effects on the welfare of a large segment of the population (e. g., agriculture in the past, and perhaps housing in the future) and either:

(a) The private sector is too fragmented for any single entity to be able to finance a meaningful feasibility demonstration, or

(b) The risks of failure, the length of the effort and the total size of the investment, combined with the relatively small fraction of the resulting economic value that might accrue to the developer, contribute to the discouragement of private investment (e. g., nuclear reactors, high speed transportation); or

(c) Antitrust laws or the regulated character of an industry prevent the necessary early R&D investment, or

(d) Social returns appear to be so high that acceleration is required, or

2. There is a set of phenomena newly discovered or not yet sufficiently explored (e. g., high energy lasers) where basic research investigation appears likely to lead to new insights

of significant importance to the government or to the possibility of creating a wholly new industry; or

3. A great variety of payoffs are expected but R&D are not profitable to individual firms because of the narrowness of their product interest relative to the range of R&D application (e.g., social research on cities); or

4. The generation of the requirements themselves require substantial investment in R&D. This is particularly true of completely new technologies whose applications are not easily foreseen (e.g., nuclear energy, space, high power lasers), or

5. Threats to our international trade balance justify cost sharing by the government (but to be limited both in size and in time) to accelerate the coupling of new technologies to products, thereby gaining international competitiveness in world trade.

IV. Adequate mechanisms should be developed for the full and extensive exploitation of the fruits of R&D. For example, built into the mechanisms for federal support of R&D should be the means for expeditious and timely transfer of the effort as well as the funding responsibilities, when it becomes appropriate, to

mission-oriented agencies, state governments, and private entities.

Therefore, the federal agencies should:

1. Establish policies and mechanisms to facilitate these transfers and formulate expressly specified plans to this end.

2. Assign the R&D work to be conducted to private or governmental organizations, chosen so as to reduce the difficulty of the transfer from R&D to exploitation.

3. Cost share if it is deemed appropriate, based on some of the above criteria, the R&D work with those elements of the public and private sectors that are most likely to benefit from the results.

V. The Federal government should encourage vigorous R&D efforts and increased productivity in the private sector by:

1. Buying to the extent feasible, on the basis of performance rather than design specifications (e.g., such items as computers, aircraft, housing etc.).

2. Setting necessary and attainable standards (e.g. in the areas of pollution, food, drugs) which industry, through imaginative application of R&D and their other talents, could profitably attain.

APPENDIX B

Members of the Science and Technology Policy Panel of the President's Science Advisory Committee (PSAC) (From February 1970 to July 1971)

Name	Function
Patrick E. Haggerty Chairman, Texas Instruments 13500 N. Central Expressway P. O. Box 5474 Dallas, Texas 75222	Chairman, Science and Technology Policy Panel
Gabor Strasser Office of Science and Technology Executive Office of the President Washington, D. C. 20506	Executive Secretary Science and Technology Policy Panel
Michael Boretsky Room 1719 Department of Commerce Washington, D. C. 20230	Member
Arthur M. Bueche, Vice President Research and Development The General Electric Company P. O. Box 8 Schenectady, New York 12345	Chairman, Educational Productivity Subpanel, and Member
Carl Savit Office of Science and Technology Executive Office of the President Washington, D. C. 20506	Secretary, Educational Productivity Subpanel
Theodore Cairns Central Research Department DuPont Experimental Station Wilmington, Delaware 19898	Member (from February, 1970 to October 1970)

William Carey Arthur D. Little, Inc., Suite 510 1735 Eye Street, N. W., Washington, D. C. 20009	Member
Edward Denison The Brookings Institute 1775 Massachusetts Avenue, N. W., Washington, D. C.	Member
Lee A. DuBridge, Former Science Adviser Apartment 3-A 2355 Via Mariposa West Laguna Hills, California 92653	Member (from October 1970 to Present)
Michael Ference, Vice President Scientific Research Station Ford Motor Company P. O. Box 2053 Dearborn, Michigan 48121	Member
Eugene Fubini Suite 816 1499 Jefferson Davis Highway Arlington, Virginia 22202	Member
Murray Gell-Mann Professor of Theoretical Physics California Institute of Technology Pasadena, California 91109	Chairman, Academic Science Subpanel, and Member (from February 1970 to August 1970)
Carl York Office of Science and Technology Executive Office of the President Washington, D. C. 20506	Secretary, Academic Science Subpanel
Philip Handler, President National Academy of Sciences 2101 Constitution Avenue, N. W., Washington, D. C.	Member

Donald F. Hornig President Brown University Providence, Rhode Island 02912	Member
John W. Kendrick Department of Economics Building C - Room 617 The George Washington University Washington, D. C. 20006	Member (From September 1970 to Present)
Richard R. Nelson, Professor Yale University New Haven, Connecticut	Member
Derek de Solla Price, Professor 2036 Yale Station New Haven, Connecticut 06520	Member
Frederick Seitz, President The Rockefeller University Sixty-sixth Street and York Avenue New York, New York 10021	Member
Lloyd H. Smith, Jr. Professor and Chairman Department of Medicine University of California San Francisco, California 94122	Member (From February 1970 to July 1970)
Robert Solow, Professor Massachusetts Institute of Technology Cambridge, Massachusetts	Member (From February 1970 to August 1970)
Chauncey Starr, Dean School of Engineering University of California at Los Angeles Los Angeles, California	Member (October 1970 to Present)
H. Guyford Stever, President Carnegie-Mellon University 5000 Forbes Avenue Pittsburgh, Pennsylvania 15213	Member

Edward Teller
Professor of Physics
Lawrence Radiation Laboratory
University of California
Livermore, California

Member (from October 1970 to Present)

APPENDIX C

Personal Positions of Individual Panel Members

July 7, 1971

1. Enhancement of Coupling Between Academic Science and Industry*

(Several Panel Members)

While a significant number of the Panel members supported two alternatives to enhance the coupling between Academic Science and Industry, there was insufficient consensus to include these alternatives in the body of this Panel Report. These alternatives are listed therefore in this Appendix.

(1) Consideration should be given to federal support for R&D at colleges and universities aimed at increasing the coupling mentioned above. It is believed that a tax credit of approximately 25% would provide a large stimulus for industry to conduct sizable research and development at our colleges and universities and still have the sponsoring company influence the direction of the research and development effectively since it still would be paying between 25% and 30% of the R&D (after offsetting the expense of the R&D itself by federal income taxes). Probably the impact of the tax credit would be both to increase the total research and development at

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*Also see Item 6, Section IV. page 3.

universities and colleges and also to substitute some privately supported effort for the $1.7 billion of support for academic science presently coming from the federal government. Companies and universities should be allowed to arrive at whatever type of mutual agreement seems best to each.

(2) Consideration should be given to some formula for Matching Funds, where industry support of R&D at colleges and universities would be matched in some manner by federal funds.

July 7, 1971

2. Comments by Edward Teller

It appears necessary to emphasize that anti-technological trends, particularly among our young people, are becoming prevalent. The result is a crisis in Science and Technology. The report of the Panel pays limited attention to the causes, the existence and the cure of this crisis.

The problem is both important and difficult. I can offer no satisfactory answers.

The first step, however, is to recognize the existence of the crisis. More of our young people believe that we have too much technology and relatively few assert that we still have too little. Ecologists argue for controls rather than for research to find the right procedures. Opposition to defense oriented research is rampant. This endangers the safety of the Nation.

As to the causes: I suspect that overemphasis on "pure" research has led to a sense of futility. It is also true that world-wide emotional trends play an important role. I doubt that systematic research will unearth the underlying causes. But careful , wide-spread and continuing discussion may offer some enlightenment.

As to the cure: This portion of the problem is the most important and most difficult. It is particularly difficult to organize the future-oriented, infinitely varied and imaginative work in Research and Technology by a staff of professionals in OST as the report recommends. Good men on short tenure (3 to 6 months) may be more helpful. Professionals with long tenure and of high quality will still be needed to orient the newcomers, to preserve their contributions and to present the resulting ideas and conflicts. Resolutions of problems and recommendations must - in the end - come from the President's Science Adviser.

To build bridges between industry, government labs and academia is most desirable. In view of troubles at our universities such bridge building may be quite difficult. Support should be given to universities where orderly work continues and where cooperation with industry and government is truly welcome.

One step in the right direction would be abolition of secrecy in Research and Development efforts. Even a short time ago this proposal may have been considered visionary. Evidence and public sentiment make it more probable that such a measure may be introduced at the present.

The utilization of categories described in Appendix A could be illustrated by the following table which crudely estimates the distribution of present expenditures (the first figures given).

TABLE I

Relative Federal Funding (estimated at present and proposed (in brackets)

Motivation of Activity \ Nature of Activity	Exploratory Basic Science Research	Applied Research and Technology	Engineering Actual Implementation	Total
Support of Goals (National & Industrial)	1% (3%)	15% (22%)	54% (40%)	70% (65%)
Education of Scientific & technical manpower	7% (4%)	4% (8%)	9% (8%)	20% (20%)
Knowledge Building A cultural Activity	2% (3%)	1% (5%)	7% (7%)	10% (15%)
Total	10% (10%)	20% (35%)	70% (55%)	100%

It may be of advantage, looking at the table to shift emphasis in the support of goals from Engineering to Applied R&D, thus reducing the probability of failures such as the F-111.

It would also appear that to spend 7% in education on the exploratory phase (i. e. about 2/3 of all the effort on the exploratory phase) is too much. Applied Research and Development should in general be expanded.

Knowledge building, on the other hand, is underemphasized. The 10% mentioned in the "Total" column could be stated only because of the 7% under "Engineering" due mainly to the space effort.

A proposed change in distribution is indicated in brackets in the Table. The main shift is from Engineering to Applied R&D which is proper in a phase of rapid development in technology.

July 7, 1971

3. Comments by Chauncey Starr

Subject: Proposed study of the dynamics of our national technology systems

The complexity of the interaction of science and engineering with the social and economic welfare of the country has been recognized by our panel in its past discussions of specific issues. However, I do not believe that anyone has adequately expressed (either quantitatively or qualitatively) the nature of the interaction network, the time constants involved, the leverage effect on the economic system, and the impact on our worldwide posture. In the absence of such system presentation, we constantly face a hurdle in communicating to the key decision centers of our federal government the significance of our recommendations. I believe therefore that the most fundamental contribution our panel can make would be the development of the principal features of the role of technology in shaping our national future.

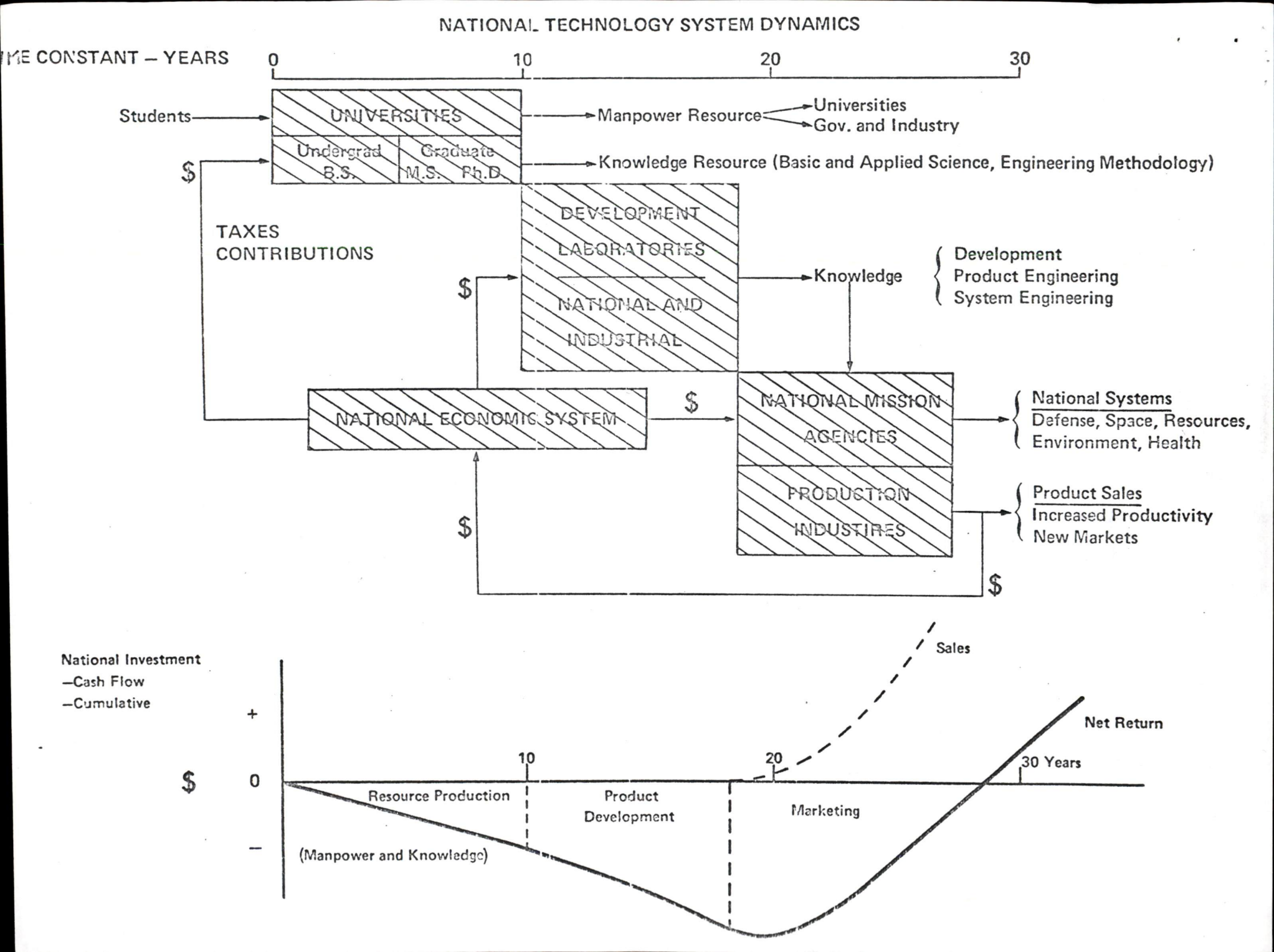
I believe that such a system model can be assembled with a reasonable amount of study if one is willing to accept approximate and judgmental relationships in some of the important areas. As a starting point for discussion of this subject, I have attached a rough sketch of the principal elements that might enter into such a network. I would expect that a group that combined experience in research, development, manufacturing, marketing, and national economics might be able to supply enough insight to the principal relationships that a working and useful model would result.

The value of such a model is potentially so great that I believe that the attempt to achieve it should be undertaken expeditiously. The model could be used to determine our long-range plans for technical manpower, to establish a rational level of basic science support, to determine national incentives for stimulating industrial R&D, and also to create a much better public comprehension of the importance to technology development to our total national well-being. *

I have some general notion as to how such a task should be approached. It can be done directly as an OST panel effort, drawing upon the information resources and intuition of the panel members. Alternatively, it might be organized by a panel but conducted by separate sub-project groups, perhaps

*It could also be used to guide the future goals of higher education (universities) and the optional university reorganization to achieve these.

funded by OST or the NSF. Another possibility would be the organization of a summer task force at a university. Although there may be a variety of suitable places, I would conceive for example of this being possible at UCLA in the summer of 1972. This coming year could then be utilized for planning the study and arranging for the commitment of individual services. An OST panel could then function as the principal review and policy group for such a study.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PRODUCTION INDUSTIRES
Product Sales
Increased Productivity
New Markets
National Investment
–Cash Flow
–Cumulative
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Sales
Net Return
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30 Years
Resource Production
Product Development
Marketing
(Manpower and Knowledge)

4. Comments by Fred Seitz

5. Comments by Art Bueche

6. Comments by Dick Nelson

7. (Comments by others)

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APPENDIX D

A DESCRIPTION OF 9 VOLUMES OF REFERENCE INFORMATION AVAILABLE

GENERAL

Since its inception in 1970, the PSAC Panel on Science & Technology Policy has amassed a substantial quantity of information in the form of letters from its members, testimony of witnesses to Congressional Committees, presentations, papers, and other documents, as well as books on subjects pertaining to its mission.

In the intial phases of collecting this information to assist the Panels' work, the most pertinent documents were "abstracted." These abstracts attempted to present clear, concise, factual summaries of the documents, which were both elaborations of the titles and condensations of their content.

During the course of abstracting, it was often found that many of the salient points were overlooked or so abridged that they lost their meaning. So, a technique, known as "extracting" was employed to overcome these shortcomings inherent in abstracting. The extracts thus attempted, not only to provide the salient points of the documents, but to present them in the author's own words, from which direct quotations could be made. The extracts also eliminated the less relevant material to compress the size of the documents for quicker comprehension. Furthermore, each extracted item was written to "stand alone," so that, if removed from its surrounding text, it would make sense by itself.

The greater portion of the most pertinent extracts were placed in machine readable form with the thought of being able to rearrange the various items contained in each extract under appropriate subject headings in alphabetical order. Thus, if a Panel member wished to see what had been written on a certain subject by various authors, he would be able to do so by merely looking up that subject. This information has been presented in machine printed form for reference by the Panel.

Hence, it can be seen from the above, that there are "abstracts" and "extracts" of much of the material, and a collection of items taken from the extracts arranged by their subject categories, in alphabetical order.

In addition to this, the Panel letters were collected and bound, for convenience into four volumes with appropriate indexes.

A more complete description of all this information compiled for reference of the Panel members and others involved in formulating Science & Technology Policy, is presented below:

DETAILED

The information is contained in 9 bound volumes, as follows:

Vol. I - Contains: Extracts from the Literature on Science and Technology Policy,

Including, among others:

The statements of:
Dr. Lee A DuBridge, Office of Science and Technology,
Myron Tribus, Asst. Secretary of Commerce, and
Robert C. Seamens, Jr., Secretary of the Air Force, before th
Daddario Subcommittee on Science, Research and Development,
Committee on Science and Astronautics, U.S.House of Representatives.

Toward a Science Policy for the United States, the final report of the Daddario Subcommittee on Science, Research and Development.

The OECD Reports, entitled:
Reviews of National Science Policy - Canada
Reviews of National Science Policy - Italy
Reviews of National Science Policy - Japan
Reviews of National Science Policy - (West) Germany
Science Policy in the USSR.

Federal Funds for Research, Development and Other Scientific Activities, National Science Foundation, NSF 70-38, 1970.

Federal Support of Applied Research,
Committee on Public Engineering Policy,
National Academy of Engineering, 1970

Trends in U.S.Trade and the International Competitiveness of U.S. Industry,
Boretsky, M. and McKibben, R.
Technological Gap Program, U.S.Department of Commerce.

Probable Levels of R & D Expenditures in 1970 - Forecast and Analysis.
Fisher, W.H. and Lederman, L.L.
Battelle Memorial Institute, Columbus Laboratories, 1970.

The Behavioral and Social Sciences: Outlook and Needs.
National Academy of Sciences
Prentice-Hall, Inc., Englewood Cliffs, N.J., 1969

Federal Policy for Science and Technology - An Interim Report to Dr. Lee A. DuBridge
PSAC Panel on Science and Technology Policy, 8-31-70

The Higher Learning, The Universities and the Public.
Carl Kaysen
Princeton University Press, 1969

Vol. II - Contains A Machine Index of the Items from the Extracts on Science & Technology Policy - by Subject Category.

These are the most pertinent items taken from the extracts contained in Vol. I and arranged by their subject categories, in alphabetical order.

The items are so numbered that they can be traced to their parent document by reference to the Document Index provided.

This document was generated by placing the extracts in machine readable form, cataloging them by their subject content, and machine ordering them by their subjects.

Where an item applies to several subjects, its listing will be repeated under these other subjects.

At the end of this volume is a listing of the Subject Catagories used in the cataloging process.

Vol.III - Contains: Abstracts from the Literature on Science and Technology Policy.

(Note that "abstracts" are different from "Extracts" as previously indicated).

These are abstracts of such material as:

U.S. Dept. of Labor, Bureau of Labor Statistics:
Employment and Earnings, Vol. 16, 1970
Population Survey, Rept. 313, Ser. p-23, 1967
Area Trends in Employment and Unemployment, 1970

Articles on Science and Technology Policy taken from the periodical literature, such as:

Science	Business Week
Physics Today	Harvard Educational Review
Scientific American	Fortune
Nature	Bul. of the Atomic Scientists

NAE and NSF Reports:
A Study of Technology Assessment - Report of the Committee on Public Engineering Policy, NAE, 1969.
Knowledge Into Action: Improving the Nation's Use of the Social Sciences, NSF, 1969

Science and Technology: Tools for Progress
Ruben F. Mettler
President's Task Force on Science Policy, 1970

Papers by international authorities on the various phases of science.

Presentations on the Funding of Science, Technology Assessment and Crime Control.

Presentations to the Daddario Subcommittee on Science, Research and Development, Committee on Science and Astronautics, U. S. Congress:
A Recommendation for Centralization of Federal Science Responsibilities, 1970
Technology: Processes of Assessment and Choice, 1969
Technology Assessment - DuBridge, Dec. 1969

Vol. IV - Contains Abstracts & Extracts from the Literature on Science & Technology Policy

This is a collection of all the extracts and abstracts contained in Vols. I and III, plus other abstracts of lesser quality than those in Vol. III. This does not imply that the articles and documents were of smaller significance, but merely that the added abstracts were not quite so well written as those contained in Vol. III.

Vol. V - Contains The most recent Panel letters from March 1, 1971 to the last letters generated by the Panel in June 1971.

Vol. VI - Contains The Panel letters from January 1, 1971 to February 28, 1971

Vol. VII - Contains The Panel letters from June 1, 1970 to December 31, 1970

Vol. VIII - Contains The Panel letters from the commencement of the work of the Panel in February, 1970 to May 31, 1970

Vol. IX - Contains the following documents which were separated from the other Panel letters for ease of reference:

(1) Report of the PSAC Subpanel on Academic Science to the PSAC Panel on Science and Technology Policy, 6-7-70. Murray Gell-Mann, Chairman.

(2) Progress Report and Observations of Science and Technology Policy Panel.
Submitted to Dr. Lee A. DuBridge, Chairman PSAC, June 5, 1970, by Patrick E. Haggerty, Chairman.

(3) Federal Policy for Science and Technology - An Interim Report of the PSAC Panel on Science and Technology Policy
Submitted in a letter, dated Sept. 9, 1970 to Dr. Edward E. David, plus a covering letter to Dr. Lee A. DuBridge, dated Aug. 31, 1970, by Patrick E. Haggerty, Chairman.

(4) On Increasing National Productivity Through Education and Technological Change.
A Report by the Subpanel on Research and Education to the PSAC Panel on Science and Technology Policy
Arthur M. Bueche, Chairman. Drafted May 24, 1971.

INDEXING: All documents contained in these nine volumes are indexed by Title and Author, Alphabetically.

The Abstracts and Extracts are also indexed by an Accession Number given them in the cataloging process.

The letters are arranged in chronological sequence.

[COMMITTEE PRINT]

REPORT OF

The Hon. George P. Miller

CONGRESSIONAL ADVISER TO THE U.S. DELEGATION

AT THE

MEETING OF THE MINISTERS OF SCIENCE

ORGANIZATION FOR ECONOMIC COOPERATION AND DEVELOPMENT

TO THE

COMMITTEE ON SCIENCE AND ASTRONAUTICS U.S. HOUSE OF REPRESENTATIVES

NINETY-SECOND CONGRESS

FIRST SESSION

Serial K

November 1971

Printed for the use of the Committee on Science and Astronautics

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FOREWORD

On October 13 and 14, 1971, the Ministers of Science of all the member countries of the Organization for Economic Cooperation and Development (OECD) met in Paris to discuss the role that science and technology will or should play in world affairs during the next decade.

It was my privilege to serve as the Congressional Adviser to the United States delegation at this Science Ministerial Conference.

In view of the great changes that are taking place in the science-economic phase of world affairs, and in view of the great importance which this phase has for the future well-being of the United States, I believe it is incumbent upon me to make this brief report of the occasion to the Committee and to the Congress.

George P. Miller, *Chairman,*
Committee on Science and Astronautics.

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I. BACKGROUND OF THE CONFERENCE

I. BACKGROUND OF THE CONFERENCE

Origin, Organization and Aims of the Organization for Economic Cooperation and Development

The Organization for Economic Cooperation and Development (OECD) was formulated in 1961 as an expanded successor to the original Marshall Plan Organization for European Cooperation.

During the closing years of the latter's existence changing economic conditions throughout the world, and in particular the increasing drawing together of the industrialized countries, seemed to call for new elements for international economic cooperation. By this time the dollar gap had virtually disappeared, quantitative restrictions on trade within Europe were largely eliminated, and a return had been successfully made to an advanced degree in currency convertibility. As a result, it was becoming apparent that the policies of any individual country had a direct and unavoidable influence, good or bad, on economic conditions in every other country.

This increased interdependence of similarly oriented countries was the rationale which lay behind the formation of the OECD and its expansion to include nations outside of Europe. It was hoped that such a grouping would be enabled, by acting together, to give a higher priority than in the past to the problems of the less developed countries. Also, a number of trade problems remained unsolved, problems which a wider circle of member nations might be expected to handle in a more efficient manner.

Subsequently, therefore, the OECD was formed adding Canada and the United States to the European nations already involved. Since that time the membership has continued to grow and the complete membership of the OECD is now as follows: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom and United States. New Zealand and Yugoslavia have special affiliations.

Without going into details with regard to the organization and aims of the OECD, it is nonetheless possible to gain a quick notion of both areas by noting the major fields of endeavor with which the OECD is concerned. These are as follows: economic affairs, environment, development assistance, international trade, financial affairs, science and education, manpower and social affairs, industry and energy, agriculture and fisheries, and nuclear energy.

The Paris Meeting of 1971

The meeting of the Ministers of Science of the OECD countries held in Paris, October 13 and 14, 1971, was the fourth plenary session of its kind but the first convened by the OECD since 1968.

The basic description of the meeting was quoted as "Science and Technology for Society." As indicated by the Secretariat prior to the

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conference, it was noted that particular attention would be given to four areas of governmental interest. These were: (a) the changing patterns of national research and development priorities toward qualitative objectives; (b) the encouragement of technological innovation in the context of economic growth; (c) the need for innovation in the social and service sectors; and (d) international cooperative projects designed to assess technological options for social and environmental improvement.

Theme of the Meeting

In fact, the general theme and tone of the Ministerial Conference was to a considerable extent based on a report made by a special "Ad Hoc group on new concepts of Science Policy." This group was formed in 1969 and composed of specialists in the field from Denmark, France, Italy, Japan, Switzerland and the United States. The group was chaired by Dr. Harvey Brooks, Dean of the School of Engineering and Applied Physics, Harvard University.

The ad hoc group's report, "Science, Growth and Society," the conclusions and recommendations of which are set forth in the attached documents to this report, clearly delineated the problem facing OECD countries with respect to the utilization of science and technology.

Reduced to simple terms, the report, and the thrust of the Ministerial Meeting, emphasized the fact that all the developed nations of the world are undergoing a marked metamorphosis in the mode and objectives of their scientific and technological development. To a great extent this appears due to the change in emphasis from the application of technologies on such matters as security and space to the great social problems being visited upon these countries today. The latter are too well known to require complete listing, but obviously include such social needs as environmental quality, health and education, urban development, transportation and the like.

The big question was, and still is, how can this transition be effected with reason and dispatch?

The U.S. Delegation

The U.S. delegation to the Science Ministerial Meeting was headed by Dr. Edward David, Jr., Science Adviser to the President and Director of the Office of Science and Technology in the Executive Office of the President.

Other members of the delegation were as follows:

Alternate Representatives:

The Honorable Joseph A. Greenwald, Ambassador, Head of Permanent Delegation to OECD.

John V. N. Granger, Deputy Director, Bureau of International Scientific and Technological Affairs, Department of State.

Congressional Adviser:

The Honorable George P. Miller, Chairman, Committee on Science and Astronautics, U.S. House of Representatives.

Advisers:

David Z. Beckler, Executive Assistant to the Director, Office of Science and Technology, Executive Office of the President.

Raymond L. Bisplinghoff, Deputy Director, National Science Foundation.

James Peter Dodd, Bureau of European Affairs, Department of State.

Hubert Heffner, Professor of Applied Physics, Stanford University.

Philip W. Hemily, Science Adviser, U.S. Mission to OECD.

Leroy F. Percival, Jr., Counselor, U.S. Mission to OECD.

The Honorable James Wakelin, Assistant Secretary for Science and Technology, Department of Commerce.

Helgard Wienert, Bureau of International Scientific and Technological Affairs, Department of State.

Staff to U.S. Delegation

Dr. Norman Neureiter, Office of Science and Technology.

Mr. John Lannon, Office of Science and Technology.

Mr. John Birch, Department of Commerce.

Mr. Philip Yeager, Professional Staff, Committee on Science and Astronautics, U.S. House of Representatives.

II. AMERICAN PHILOSOPHY PRESENTED

II. AMERICAN PHILOSOPHY PRESENTED

In accordance with the main goal of the Science Ministerial Meeting, which could perhaps be paraphrased as the integration of science policy with social and economic policies, the United States delegation chose to limit its major input to three broad areas. These were:

1. Trends and objectives of individual countries within the framework of international cooperation;
2. Innovation in society and the results of such innovation on the economy;
3. International cooperation in science and technology and what might be expected from it.

A condensed statement of the American philosophy and discussion in each of these areas, as expressed both during working sessions of the U.S. delegation by itself and in the course of the plenary ministerial sessions, was in the following vein.

Trends and Objectives

It is clear that an invigorated Research and Development program could be an important tool in meeting the challenges inherent in these situations. It is worth noting that not all segments of opinion would agree that Research and Development is a key to productivity, trade and jobs. Many economists believe that manipulation of economic variables can provide solutions. Most of us agree that in the short-term they can. The longer term, however, calls for programs with substance to produce new products and new industries.

The Executive branch's Office of Science and Technology, for example, has worked with many people in the Federal agencies and departments and with outside consultants to uncover promising ideas. This represents a creative effort on the part of the U.S. government and the research community which goes considerably beyond efforts made in the recent past. The proposals range from advanced transportation systems to increased protection from natural disasters and improved air quality. None of them seems feasible except through technology-intensive systems or products. All of the proposals also include a strong quality-of-life component, almost routinely, which indicates the determination of the United States to reconcile high technology with human environmental considerations.

Such an approach is exemplified by the energy message which President Nixon sent to Congress last June. The message sought to identify technological oportunities to reconcile the conflict between increasing energy demand and the depletion of natural resources, with due regard for environmental quality.

Just as the integration of science policy with economic and social policies is important in national governments, it is also important in international organizations. In this regard, the OECD can play

an enormously useful role in examining policy issues that are common to member governments by taking a "horizontal approach" in bringing to bear the diverse skills within the Organization, thereby demonstrating and encouraging the analytical techniques and synthesis which are necessary at the national level.

Innovation in Society and the Economy

The American delegation pointed out that successful technological innovation requires the presence of three factors: scientific and technological capability, market demand and an agent which transforms this capability into goods and services which satisfy the demand. In this commentary the delegation agreed with the report of the OECD Committee for Science Policy (the so-called Brooks Committee), adding that the agents in the transfer of technology to the market place are industrial firms, the universities and the governments.

In the elaboration of the foregoing position, the delegation cited the following experience of the United States up to this point:

1. In the United States the government has played both a direct and indirect role. One key example of the direct role, which has been in operation for more than a century, is the Federal stimulation of innovation in agriculture.

2. In more recent years, the United States government has influenced technological innovation in less direct but equally significant ways. There seems little question that the large investments in military and space research and development have resulted in innovations in many important products such as aircraft, high performance materials, integrated circuits, computers, lasers, sensors of many kinds and a host of other applications.

3. Unlike the military and space programs where the government is the consumer, the government also plays a role in the creation and aggregation of markets as a key to large scale innovation in the public sector. One example is the financial incentives offered through cost-sharing as a means for stimulating new approaches to housing and building systems.

4. An important function of the government is not only to support technological developments, but the conduct of carefully controlled demonstrations that would provide visible evidence of technological feasibility as well as a better basis for economic evaluations in the diffusion of innovation throughout the country. An example here is the standard setting through Federal action which tends to benefit the general public, as in the case of air and water pollution controls, quality of consumer goods, and programs designed to aid education and health, etc.

5. The government is presently examining a range of incentives for increasing Research and Development innovation aimed generally at economic growth and increased productivity—with special emphasis on means of encouraging the entrepreneur and the small company with a new technological idea.

6. The advanced and widespread goal of the university in the innovation process is well known. We have seen the results of research innovation from universities in every field from the hard engineering sciences to the social sciences and the development of sophisticated software where automatic data processing is concerned.

7. American experience has shown that government policies for the stimulation of innovation are shortsighted and incomplete unless they rest on a sound understanding of the possible effects of the introduction of such innovations, economic, social and environmental. Consequently, efforts are going forward now to develop appropriate methods of "technology assessment" as a mode of measuring the impacts of technological use in every area of society, as well as "social indicators" which could provide a basis for quantitative measurement of social cost and social benefit.

Through the exchange of experiences, such as those outlined in the foregoing, between OECD nations, the delegation expressed the desire for rapid innovation in civilian industry and in the service sector. In addition to such exchange of experience, the delegation discussed the role of the multinational firm in the transfer of technology and, in the course of the plenary sessions, emphasized the need for studies to project and assess the effects of governmental efforts to stimulate technological development in the private sector.

International Cooperation in Science and Technology

Without recounting the many benefits of international cooperation, the Americans emphasized that the amount and necessity of international scientific and technological cooperation can only increase. Thus, it appeared timely that we accept and implement the recommendation of the Science Policy Committee that "OECD should help to develop the understanding of the member countries as to appropriate means of selecting topics, criteria of participation and institutional forms appropriate to different scientific needs." Emphasis was given to the recommendation that the OECD analyze its own experience and the performance of selected international programs and projects as well as bilateral schemes.

In the deliberations of the OECD Committee for Science Policy, the need for increased international cooperation in science and technology in the coming years is well recognized. This is particularly true in applied research in the public sector; in basic scientific research, including "big science" and in dealing with regional or global environmental problems. The United States affirmed that the OECD can plan an important role in bringing about cooperation among countries who share many common aims and objectives and who are dedicated to the application of science and technology for the benefit of their citizens and those of other countries which have just begun to climb the economic ladder to a better life.

Several U.S. proposals, intended to be a first step in the direction of implementing the recommendations of the (OECD) Science Policy Committee, included the following:

1. To promote cooperation in projects of basic research involving large installations and equipment where there would be advantages in making large scale equipment internationally available, it was suggested that examination be undertaken of a mechanism for utilizing most effectively the limited scientific resources of OECD members in support of the "big science" of astronomy—to maximize the research

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results for a given level of investment in new facilities. To this end it was proposed that the Science Ministers ask the OECD Science Policy Committee to explore the concept of coordinated planning and utilization of future facilities for astronomy.

2. To encourage international cooperative arrangements between and among member countries, elements of which could be undertaken by various national institutions, it was suggested that a meeting be called of OECD members to consider the research needs in environmental health, to review the advantages of cooperative arrangements among nations for the performance of this research, to take account of existing international programs, and to consider the place of existing international organizations such as the OECD, World Health Organization and Food and Agriculture Organization in fostering this effort.

It has become apparent in recent years that there are clear advantages in sharing the tasks of research aimed at understanding the effect on human health of environmental agents. The most persuasive argument, perhaps is related to the fact that the task itself is very large—perhaps overwhelming.

A second reason for encouraging international cooperation is related to the fact that some of the scientific experimentation necessary in this field is in the realm of big science. Therefore, its accomplishment is limited by logistics and resources.

3. To increase the mobility of research workers among government laboratories of the OECD countries, it was suggested that a meeting of government representatives be called to prepare an inventory of unique or outstanding research facilities which might be made available for participation by scientists from other countries. The group would be asked to prepare recommendations on specific mechanisms and arrangements to achieve this end.

III. OBSERVATIONS OF CONGRESSIONAL ADVISER

III. OBSERVATIONS OF CONGRESSIONAL ADVISER

In order to balance the presentation with regard to the manner in which the Federal government operates, it was felt useful to submit for the record of the American delegation certain observations concerning the Congressional role in the making of science policy.

This was done largely through examples of activity undertaken by the Science and Astronautics Committee of the House of Representatives.

The information and observations by the Congressional Adviser, as submitted in part, are as follows:

Examples of the Instigation of Science Policy Made by the Science and Astronautics Committee

Enumerated below are three examples of the way in which the Congressional committee either makes science policy or may assist in its formulation. They are limited to the experience of the House Committee on Science and Astronautics, but keep in mind that many other committees also deal with varying facets of science and technology—Atomic Energy Committee, Interior Committee, Commerce Committee, Merchant Marine and Fisheries Committee, Government Operations Committee, Armed Services Committee, etc.

The examples chosen from this committee's activities are these:

(a) Revision of the National Science Foundation Charter

Following a three-year review of the activities of the National Science Foundation, beginning in 1965 and culminating in 1968, the Subcommittee on Science, Research, and Development and its parent committee revised the charter of the National Science Foundation on a considerable scale. No attempt is made here to describe the changes effected; we simply point out that those changes are permitting the Science Foundation today to engage in both basic and applied research on the major problems which face contemporary American society. By far the greatest amount of this research is of a basic nature since that is the paramount function of the Foundation. Nonetheless, such research, as well as applied research, can be to some extent directed to areas where great social solutions are needed—examples: environment, urban problems, transportation, health care, unemployment, population dispersion, etc.

(b) Science Policy Study and Recommendations to the Executive

During a large part of 1970 the Subcommittee on Science, Research and Development held extensive hearings on what a science policy for the United States should consist of. Subsequently the subcommittee issued a sweeping report with broad recommendations for action by the Executive branch. Again it is unnecessary to enumerate all the recommendations, but here are some matters with which they dealt:

basic philosophy on which a science policy depends; reorganization of the Executive branch for dealing with scientific and technological matters; a proposed National Institutes of Research and Advanced Studies which would augment current Federal methods of supporting science education and research; proper funding methods for science and technology, including projections into the future by the Office of Management and Budget and OST, science education and manpower problems; international relations in the science area; social and economic phases, etc.

To date action has been taken only on several of these matters, but the report has had its effect and, we believe, has been an important input into the thinking of those responsible for Federal support of science and technology in the Executive branch.

(c) Technology Assessment

The Science Committee has also been working on the concept of technology assessment since 1966. After five years of close study by the committee and staff—and after the submission of four special studies done for the committee through contract by outside sources (the Science Policy Research Division of the Library of Congress, the National Academy of Sciences, the National Academy of Engineering and the National Academy of Public Administration)—the committee wrote its own bill proposing the establishment of an Office of Technology Assessment within the Legislative branch. The function of that office would be (1) to identify areas of developing technology which might be utilized in the solution of the nation's problems and (2) to serve as an early warning system against possible unwanted side effects of such technology.

For the most part such assessments would be made in cases where the Congress was being called upon—or expected to be called upon—either to support or regulate a particular program of marked technological content. Assessments could be instigated by the chairman of any Congressional committee, acting for himself or for a majority of his committee members, or by the director of the Office or by the governing board of the Office.

Again, it seems unnecessary to describe the technology assessment concept in detail. It is well known to members of this body.

Suffice it to say that if we succeed in establishing the Office, it will be the first new information system which Congress has developed for its own use since the Legislative Reference Service was set up in 1915.

The Range of Areas of Interest of the Committee on Science and Astronautics

For those who may be interested in the diversified nature and in specific areas of inquiry in which the House Sciences and Astronautics Committee has been involved, there follows a list which incorporates most of those activities—in addition to the space program—during recent years:

Federal science policy
- Identify problems and assign priorities
- Basic research and national goals
- Government, science, and public policy
- Inquiries, legislation, policy studies
- Applied science and technological progress
- Science, technology, and public policy
- Policy issues in science and technology
- National science policy

Funding and geographical distribution of Federal R. & D. programs
- Funding of R. & D. programs
- Geographical distribution of Federal R. & D. funds
- Indirect costs associated with Federal support of R. & D.
- Mission agency support of basic research

Aeronautics
- Panel meeting, 1964

Science education
- NSF science education reports
- Federal Government and higher education
- Institutional grants for science education

National Science Foundation
- Review of charter

Authorize appropriations for the National Science Foundation
- Conversion of research and educational programs from military to civilian activities

Science information systems and handling
- Communications council
- Management of information and knowledge

Standard reference data
- Bureau of Standards legislation
- Authorization of standard reference data funds

Environmental quality
- Adequacy of technology for pollution abatement
- Environmental quality
- National policy for the environment
- Environmental science activity at institutions of higher education

Fire research
- Fire research and safety program
- Authorization of appropriations for fire research and safety

Technology assessment
- The technology assessment concept
- Assessment studies and preparation
- Technology and urban problems
- Methods of technology assessments previously used by Congress
- An assessment of the Vietnam defoliant matter
- Technology assessment legislation
- Annotated bibliography

Management of Federal scientific activities
- Reallocation of Federal science resources
- Centralization of Federal science activities

International science
- International programs of Federal agencies
- Government, science, and international policy
- International biological program
- Applied science and world economy

International cooperation and legislative method in science
Multidisciplinary or systems studies
National goals in science and technology
Multipurpose missions
Interdisciplinary research

Science, Technology and the Economy

It will be of special interest to this group to note that in the course of the Committee's science policy hearings held a year ago last summer, it became apparent that one of our major problems—both on a domestic and an international basis—was the relationship between science and technology on the one hand and the economy on the other.

Preliminary investigation disclosed that the committee had far too little information at its fingertips to permit the start of a close and careful investigation of this problem. Thus the Committee began planning for a series of comprehensive hearings on the subject and spent the better part of a year in preparation.

By this past July the Subcommittee on Science, Research, and Development completed a preliminary series of hearings, which dealt with the matter in a broad general way—but in a way sufficient to permit further planning.

Those hearings, it should be added, produced the now well-known commentary of Secretary of Commerce Maurice H. Stans, who delineated the Administration's own concern and interest in the broad area of technological economics.

Since that time the Subcommittee on Science, Research, and Development has met with its special Research Management Advisory Panel to discuss avenues of further inquiry next year, as well as identify persons who can contribute the best information. Such witnesses, of course, will be drawn from industry and the academic world as well as from government and international experts.

The members of the Research Management Advisory Panel are as follows:

James B. Fisk, President, Bell Telephone Laboratories, Inc.
James M. Gavin, Chairman of the Board, Arthur D. Little, Inc.
Samuel Lenher, Vice President and Adviser on Manufacturing, E. I. du Pont de Nemours and Co. (Ret.).
Wilfred J. McNeil, President, Tax Foundation, Inc.
Don Price, Dean, John F. Kennedy School of Government, Harvard University.
C. Guy Suits, Vice President and Director of Research, General Electric Corp. (Ret.).
Jerome B. Wiesner, President, Massachusetts Institute of Technology.

Following conferences with the Panel and after a study of their deliberations, it is the Committee intent to begin a more comprehensive and wide ranging inquiry into the role of science and technology as it interrelates with national and international economies. At this point, one can have no idea where it will lead, but it is not unreasonable to expect that the eventual findings will be of considerable value not only to those of us in the Legislative branch but to the policy-makers in the Executive branch as well.

IV. ACTION TAKEN BY OECD

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IV. ACTION TAKEN BY OECD

At the conclusion of the Science Ministerial Meeting, the OECD Ministers issued a joint communique which was based on the following unanimous conviction:

That science and technology will continue to be essential elements in social and economic progress, that science and technology should contribute more fully to the improvement of the quality of life as well as to material well-being, and that the undesirable side effects of technological applications must be controlled.

The ministers outlined three basic goals toward which the OECD should strive—these being essentially the expansion of research to meet social needs, the stimulation of technological innovation as an economic measure, and more effective management of technology in the basic interest.

In addition, the ministers defined a number of fields in which work should be undertaken and in which the OECD and national staffs are already engaged. The areas stressed are primarily these:

1. The accumulation of more basic knowledge and its relation to social problems.
2. Changing requirements for scientific and technological manpower.
3. The growing importance of social objectives requiring increased use of social science.
4. The need for closer links between economic, social, scientific and educational policy-making at all levels of government, national and international.
5. More accurate information and the accumulation of better baseline data on which decisions can be made.
6. The stimulation of improvements in the industrial innovation process.
7. Stimulation in the public sector for market incentives which presently are partly or wholly absent.
8. Improved understanding of the research activities and the market mechanisms of multinational firms.
9. The assessment of the adverse and beneficial consequences of technological development.

A number of specific recommendations were also made in two other major areas. One of these was promoting research cooperation between member countries of the OECD; the other included the evolution of science and technology for developing countries.

Details of the communique may be found in Part VI of this report in their entirety.

V. SIGNIFICANCE OF THE CONFERENCE

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It appeared that one of the most significant elements about the Science Ministerial Meeting of the OECD, recently concluded, was the fact that the meeting was held at all.

This was only the fourth meeting of the OECD Science Ministers since the founding of the organization. It demonstrated conclusively that, so far as these 25 industrialized nations are concerned, a tangible metamorphosis is underway with regard not only to the applications of science and technology in the future, but in the role of governments in regard thereto and in the management and control of the applications of these various disciplines.

There could be little doubt that the kind of scientific reappraisal which has been underway in the United States for the past several years is not a phenomenon limited to our country—in spite of the fact that we have been a leader in technological development in the two areas which have been most seriously affected; that is military and space. The phenomenon appears to extend in relative degree to virtually all of the other nations of the world which depend on technology in any significant way.

Goals of the Science Ministers

The very nature of an international conference such as the Science Ministerial Meeting under discussion almost requires that the conclusions and recommendations deal in generalities and, sometimes, in platitudinous statements. Certainly these were not lacking in some of the proceedings and statements of this conference. At the same time, it would seem important to note the rather concrete language of the three goals specified by the conference as the objectives of its science policy in the 1970's.

Specifically, these are:

1. "Expansion of research, development and innovation activities to meet social needs such as environmental quality, health, education and urban development.
2. "Continued stimulation of technological innovation in the economy to achieve qualitative as well as quantitative growth.
3. "More effective management and control of technology in the public interest."

Meaning for the United States

It would appear that the message contained in the activities of the Science Ministerial Meeting of the OECD is clear.

It is this.

First, there is a change of emphasis in the way science and technology will be used in the future and in the problems and concepts toward which they will be applied. Principally, as mentioned in

the foregoing, this means concentration on the applications of technology to the kind of social needs and life-quality standards which the OECD nations have in common and to which they have proclaimed their dedication.

Second, more international movement and involvement seem unavoidable. It must be kept in mind that powerful new economic blocs have been formed and more are in the making. These include not only the Common Market which, with the advent of England's participation, can be expected to be extremely influential on a worldwide basis, but the economic development and solidarity of the Soviet Union and its neighboring countries; the emergence of China as an economic as well as a political force in the world; the continued high momentum of Japan in a very large number of successful economic fields; and the development of our neighbor to the north, Canada, as her vast resources come into greater prominence as a factor in world trade.

Third, in situations such as these, it would appear that the United States has little choice but to participate in this worldwide economic ballgame. It is not suggested here that America desires to do otherwise, but only to note that the alternative of following our own bent to the exclusion of the interests of other countries is probably not an option that is open to us.

Fourth, how well the United States fares under these evolving conditions will, to a great extent, depend on how thoroughly and consistently we support our Research and Development and on how astutely and perceptively we manage the applications of the results—economically, socially and politically.

VI. ATTACHMENTS

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Paris, 14TH OCTOBER, 1971.

COMMUNIQUE

MEETING OF MINISTERS OF SCIENCE OF OECD COUNTRIES

1. The Ministers met under the Chairmanship of Mr. Wataru Hiraizumi, Minister of State for Science and Technology of Japan, in order to review the progress of science and technology in OECD countries and to consider the orientation of science policy in the 1970s to meet social and economic needs.

2. They reaffirmed their conviction that science and technology will continue to be essential elements in social and economic progress in Member countries. At the same time they stressed that science and technology should contribute more fully to the improvement of the quality of life as well as to material well-being, and that the undesirable side-effects of their application should be controlled.

Goals for Science Policy in the 1970s

3. Ministers agreed that the 1970s will require new efforts by Member Governments in three main directions:

—expansion of research, development and innovation activities to meet social needs such as environmental quality, health, education and urban development;

—continued stimulation of technological innovation in the economy to achieve qualitative as well as quantitative growth;

—more effective management and control of technology in the public interest.

4. Welcoming the continuing OECD work in the field of science policy, Ministers invited the Organization to conduct a review of the progress of Member countries in developing and managing scientific and technical resources for achieving new goals.

New Directions for Scientific Research, Development and Information

5. More basic knowledge is necessary to solve the increasingly complicated problems of modern societies. Active support for fundamental research, increasingly on a multi-disciplinary basis, will thus be needed.

6. Ministers noted the rapidly changing requirements for highly qualified scientific and technical manpower, and invited the Organisation to study the conditions necessary for adaptation to continuously changing needs.

7. The growing importance of social objectives requires increased support for the relevant social sciences, including research into the

policy-making process itself. In particular, new techniques are needed for the analysis and management of complex social systems in which human, economic and technological factors interact. Realistic social indicators should be developed to guide decision-making in relation to such systems, and Ministers therefore welcomed existing OECD work on this problem. They also invited the OECD to consider convening an Inter-governmental Conference on the social sciences to identify priority research tasks, to be followed by co-operation between interested Member countries in chosen fields.

8. Recognising the many-sided character of present-day problems, which often exceed the scope of single government departments, Ministers underlined the need for closer links between economic, social, science and educational policy-making, at the national and international levels. This will call for improved methods for the formulation of policy for science and technology for which studies on research priorities, the decision-making process, the forecasting of project costs and contract procedures between government and industry could make a valuable contribution.

9. The complexity of policy decisions also calls for more and better information at all levels. The increasing interaction of computer, communications and information systems will open up new possibilities in the 1970s. Ministers invited the Organisation to strengthen its work in this field, and in particular to examine the international implications of the new systems.

Linking the Innovation Process to Social and Economic Development

10. Ministers agreed on the *need to stimulate further improvements in the innovation process* if the results of research and development are to have the maximum diffusion in society. They recommended that the Organisation should pursue its work on *industrial innovation* and, in particular, encourage the exchange of experience between Member countries on the effectiveness of relevant policies, including mechanisms for providing risk-capital. They also proposed that this work should be extended to the service sectors of the economy, in some of which widespread and effective use of technology could contribute to needed improvements in productivity.

11. Innovation in the public sector, in *which market incentives are partly or wholly absent*, may require special measures by Governments. In order to accelerate the exchange of experience between Member Governments, Ministers requested the Organisation to make studies of the potential for innovation and of the contribution of science and technology to sectors such as health, urban development, environmental protection and education. Other studies might cover effects of new developments on the work environment.

12. Ministers also took note of the growing importance in Member countries of the *research activities of multinational firms*, and invited the Organisation to undertake a study of the role of such firms in developing national scientific and technological capabilities in the Member countries, complementary to other OECD studies on the multinational firm.

Assessing the Impact of Technologies

13. Ministers recognised that a major task for science policy will be to *assess the adverse and beneficial consequences of technological development*, and to foresee scientific and technological trends. They agreed to share the effort of making such studies and to exchange the results through the Organisation, in order to develop more effective methods and evaluate national case-studies.

Promoting Research Co-operation Between Member Countries

14. Intensified scientific and technical co-operation among the OECD countries will be required in the 1970s to achieve common economic, social and environmental objectives and ensure more effective utilisation and resources for research and development. Ministers stressed the growing importance of harmonizing national efforts, as distinct from the creation of centralised international institutions.

15. Ministers also considered that continuing efforts are needed to strengthen the scientific and technological capacity of, and to study the transfer of technology to, developing Member countries.

16. They recommended that the Organisation should assemble information on the performance of international and bilateral programmes and projects, propose means for establishing better relationships between national and international efforts, and suggest to Governments the alternative solutions for dealing with new problems of international co-operation.

17. Ministers noted the continuing efforts to promote co-operation in fundamental research through the creation of centres of excellence.

18. Ministers welcomed the co-operative programmes developed by the Organisation in response to the recommendations of their 1968 Conference, notably in the fields of educational research and innovation, environmental technologies, road research and transportation, computer utilisation, scientific and technical information and the management of technology.

19. Ministers agreed that future co-operation would be strengthened by intensified mobility of research workers, and invited the Organisation to study the means for facilitating the exchange of research workers among government laboratories in Member countries.

20. They also recognized the importance of international consultation among science policy officials in Member countries leading to interrelated national research programmes. They agreed that the OECD provides a convenient and flexible framework for promoting international co-operation in this direction and invited the Organization to study the possibility of:

—co-ordination in planning the construction and international utilization of national "big-science" facilities, for example in the fields of astronomy and high-energy physics;

—collaboration between interested Member countries in research on the biological effects of toxic chemicals introduced into society including co-operation on related epidemiological studies, having regard for the work of other international organizations.

Science and Technology for Developing Countries

21. Ministers underlined the importance of the work of the Organization bearing on the role of science and technology in achieving the broad objectives of the International Development Strategy for the Second Development Decade. They agreed that these efforts will necessitate more research sponsored by Member countries specifically directed to the problems of the developing countries, and that co-operation between Member countries in such research should also be strengthened through the OECD in harmony with the activities of other international organizations.

22. It was agreed that the special experience of the developing Member countries in utilizing technology for the expansion of their economies, should be used to assist less developed areas.

[From SCIENCE, GROWTH, AND SOCIETY]

Report of the Ad Hoc Group on New Concepts of Science Policy to the OECD

Conclusions and Recommendations

Two central themes can be discerned in the situation of the OECD countries in the coming decade:

1. economic growth *per se* is no longer a sufficient overall objective, and
2. further interventions in the operation of the market economy will become necessary.

Such interventions may take three forms. The first is the alteration of the ground rules and incentives under which the market operates by such devices as taxes, subsidies, and judicial actions to internalize social costs. The second is regulations and standards in relation to such matters as safety, pollution and use of land or other scarce common resources. The third is direct economic activities of government deemed to be sufficiently in the general public interest to warrant supplementing private activities beyond the level that market forces alone would generate. These interventions will affect the allocation of investments and the direction of innovation.

The following conclusions and recommendations are addressed to the Member countries as well as to the Organization as such. We shall first indicate the changes likely to be operative in the 1970's for science policy as well as broader policy objectives, and then propose types of studies and activities that we think must be undertaken by the Member countries and by the OECD as an Organization.

Conclusions

The uncertainty and rapid change of social goals are causing, and will continue to cause, a difficult and sometimes painful re-adjustment as the scientific establishment strives to respond to new priorities. The levelling off of R & D resource growth is only one consequence of this adjustment. Massive projects in space, defence, and associated activities decline, while goals in social areas have not yet been sufficiently crystallised so that they can be related to coherent and focused technical programmes. Thus unemployed technical manpower is appearing or may appear in some sectors. Until the new social goals have become better crystallised and related to technical and scientific goals, the future demand for scientific and technical manpower will be difficult to forecast, and there is considerable disagreement about the long-term implications of present trends.

To blame the deleterious effects of technology on research and development priorities is unwarranted. These effects are consequences of

broad social and economic policies. Public disillusion with the effects of the application of technology on the quality of life of the individual, which has rubbed off onto science, is likely to increase. At present this disillusionment is manifested mainly in outcries about such disturbing effects as urban decay, pollution, and displacement of labour. In addition, there is increasing public questioning of the ethical basis of research whose results might be used for the manipulation of the individual or society. Furthermore, the shadow of nuclear warfare and the use of increasingly sophisticated destructive "conventional weapons" still remains. Thus public opinion is focusing on the negative effects rather than the benefits that society enjoys as a result of scientific discovery.

It is important to recognize that many current problems of society arise from inadequate development of technology in the services sector, in comparison with technology developed for the manufacturing sector. The very slow growth of productivity in government services and in the services sector generally, particularly in education and medical care, has been a major cause of inadequate social performance of the economic system in relation to individual and social welfare.

Further economic growth may be necessary before the advanced countries can remove residual islands of poverty, improve social services such as public health, education, and urban transportation, and increase their aid to less developed countries. However, it is now recognised that growth, as measured by the market alone, does not automatically guarantee the best application of the resources created. Thus, emphasis has shifted from growth in increased personal incomes to growth in generating the means necessary for general social development. The new emphasis entails consideration of the qualitative aspects of economic growth and of social influence upon the direction of investment and innovation.

There is now recognition that the improvement of the social infrastructure is itself an element of growth, but that, given a certain potential capacity for growth in the economy set primarily by the factors of production—including technology—changes in the quality of life will come only at some cost to other consumption, presumably of the more affluent segments of society.

In the Member countries, the complex of problems arising from high levels of affluence, concentration of people in urban agglomerations, and the side-effects of technology sets the stage for a shift of public and parliamentary attention toward social objectives. Rising levels of education and the impact of social unrest and violence publicised through world-wide mass communications have increased awareness of the critical issues.

The nature of the new problems and their complex interactions represent a challenge to which government, educational and research structures have not yet fully adapted. Our institutions reflect a division of labour within society that is adapted to the achievement of past goals and the meeting of past challenges. The new situation demands a different division of labour and new specialisations and mixes of work skills. Yet each segment of the structure tends to view the new problems from the perspective of old skills and areas of specialisation, doing what comes most naturally from past experience.

The present situation produces an overwhelming need to reassess the place of science and of particular areas of science, both in cultural terms and as the roots of the technology through which further change, improvement or deterioration will flow. When social goals are uncertain and changing, it is especially important that their formulation embody the most up-to-date available understanding of the interactions between technology, the economy, social trends, and the quality of the environment. Those responsible for the development of science policy will have to be more clearly involved in the setting of national goals and the priorities between them, if the goals are to be realistic and the system of science and technology made able to respond fully to them. Research will usually be needed to identify interconnections, inconsistencies, and conflicts between goals. Otherwise expenditures may be made inefficiently or for purposes that are obsolete when achieved.

The continuation of economic growth and the exigencies of new social goals lead us to expect further massive development of technology, but in a more comprehensive and socially oriented framework than in the past. A certain amount of catch-up may be required to reverse the deterioration that has already occurred in the quality of life. The required technological development and the advancing basic knowledge from which it must derive may demand further increases in R & D effort in the long run.

One of the most difficult and perplexing issues of science policy is the proper balance between centralised policies for science and technology considered as a single aggregate, and sectoral policy related to the particular sectors of social or economic policy served be research and development. There is no final resolution of this problem, but any viable system of science policy must involve some blend of centralised and sectoral approaches.

The United States system has emphasized the sectoral approach, with total resources being made available to sectors as a whole—e.g., defence, health, agriculture—and the appropriate R & D levels that are profitable for particular sectors which are determined in competition with capital and service expenditures in the same fields. This system tends to work most effectively in a situation in which total resources are increasing and social goals are rather stable and unchanging, so that the sectors are well defined. Thus the American approach appeared very attractive until about 1966. Other OECD countries have tended to emphasize a centralised approach, with aggregates of R & D funds being sub-allocated to research in support of various sectors. Such a scheme works better than the sectoral approach in a condition of limited total resources, when social goals are unstable and changing rapidly.

The new tasks faced by science and technology are more complex and multivariant than the old ones, involving economic, social, cultural and psychological aspects, as well as more strictly technical ones. The interweaving of these considerations, both in resource-allocation decisions and in execution, will be a major challenge to science policy, which can thus no longer be restricted to the natural sciences and engineering development. Both utilisation and further build-up of the conceptual and knowledge base of the social sciences will be matters of central concern.

Many of the problems, of course, will be managerial and political, and will continue to require mainly the traditional intuitive managerial and political skills that man has always applied in governing himself, rather than applied science. Nevertheless, we will necessarily take advantage of the knowledge, insight, and methodologies of the social sciences in dealing with the social aspects of problems such as medical care, education, pollution abatement, population policy, technical assistance, as well as national planning in such areas as transportation, housing, and rational land use.

The usual governmental responses to the necessity for coordination of policy in various sectors are of two kinds. On the administrative side there are interdepartmental co-ordinating committees, usually operating mostly at the top of the structure and at the most general level of policy formulation. Co-ordination also takes place through parliamentary processes, particularly through legislative committees and their staffs. Neither mechanism is fully effective. Administrative co-ordinating mechanisms usually do not command sufficient resources or have sufficient control over budgetary allocations to bring about reconciliation of policies over the many different levels of implementation usually required. Co-ordination of policy at the top of the structure is often eroded in the process of implementation at the separated lower levels in the vertical structures involved, and there is little feedback between the various sectors. Legislative bodies usually do not command the necessary sources of information and lack the time and attention necessary for the achievement of coherence.

Furthermore, on both the legislative and administrative sides, the need for political accountability to diverse and often conflicting constituencies tends to limit planning time. Consequently, emphasis is placed on short-term reaction to immediately perceived problems rather than on systematic consideration of longer-term and more remote consequences of policy, especially consequences lying outside the traditional spheres of responsibility of the particular agencies involved.

The selection, management, and regulation of technology will pose difficult problems; in part because this is a little-developed field, outside the range of strictly economic criteria. Techniques must be developed for the social and cultural, as well as economic, assessment of various technological options and for the discernment of errors and disbenefits implicit in certain directions of commitment. Assessment must take a broad view of technological applications, pointing out how they should fit as complete systems into society and the safe public limits on their use. The lack of such balanced assessments, carried out on a continuing basis over long periods, has led to the major social disbenefits of technological advances. The control of technology within political systems that encourage competition and pluralism and retain the profit motive represents a major challenge to industry with regard to broadening its motivation. Balance sheets of costs and benefits for particular technologies will call for considerable scientific research effort. International sharing of this effort and comparison of national experience in assessment, insofar as problems are common to many countries, could be especially fruitful. The value of such international effort takes on new importance in the light of the growing relative

contribution of multinational firms to the application and spread of technology.

Multinational firms play an important role in the diffusion and transfer of technology across the national boundaries of the advanced countries, and from these countries to the developing countries. The growing power and the high flexibility of multinational firms give rise to problems and conflict between these firms and the host countries, whose authority is often reduced, and especially when the objectives of multinational firms do not accord with the socio-economic goals of the countries in which they operate. This is of particular relevance to science policy because, in some countries, the R & D potential of multinational firms practically dominates the pattern of national science efforts. In such circumstances, there is need for reciprocal understanding between the governments of the host countries and the management of multinational firms, to harmonize the strategies of those firms with the goals of the countries in which they operate.

In many countries, science policies have tended to neglect the potential use of science in many sectoral activities. For example, bigger commitments of national R & D capabilities may be required for aid to developing countries, and this may include both efforts within the OECD Member countries on generic problems of underdevelopment and detachment of scientists and engineers to serve overseas.

We wish to stress that simple transfer of existing techniques will seldom meet the needs of the less developed countries. Modern techniques must be adapted to their situation. For example, in agriculture, existing strains of cereals and of plants, as well as breeds of cattle, etc., must be adapted to the various conditions of soil and climate. Often this requires cross-breeding and a network of local research stations.

In all activities, but particularly in industry, public works, and house construction, labour-intensive techniques should be developed because there is abundance of cheap labour but shortage of capital. A dual economy now often develops, composed of a small capital-intensive industrial sector with large production per man, the rest of the economy having very low levels of production with traditional techniques. Modern but labour-intensive techniques hardly exist, and consequently a large-scale rural exodus is involving a growing number of unemployed people, who are living in "bidonvilles" under miserable conditions. In the development of appropriate techniques for dealing with such problems, and in the examination of the fields in which they can fruitfully be applied, scientific co-operation between OECD Member countries and developing countries is required. Such assistance should include development of structures and policies, and R & D activities and mechanisms for expediting the transfer of technology from advanced countries. It should also include specific suggestions for the opening of markets in the advanced countries for the outputs of labour-intensive industrial production in the developing countries.

Other international aspects of science policy are likely to become important with the growing demands on resources and the extension of activities to which new research can contribute. The shift of emphasis towards the solution of social problems will provide many op-

portunities for scientific co-operation where the immediate competitive difficulties of technological cooperation hardly arise. Moreover, there is a whole series of activities, particularly with regard to fundamental science, requiring large-scale facilities and activities directly under government control, in which international co-operation or even cost-sharing in R & D could provide a considerable increase in the products from the use of limited resources. Such co-operation could take the form of complementarity in the planning and multinational utilisation of national facilities or of actual joint financing of international facilities.

Recommendations

The problems we emphasize are common to most of the Member countries, and many of them are unlikely to be resolved in narrow national terms. Thus there is a growing international function with regard to both the discussion and resolution of particular issues and possible co-operative cost-sharing attempts to solve many problems. OECD, as an association of the industrialised market-economy countries, with Members and interests in many parts of the world, is well placed to play the major role in this field, not only because its Member countries, because of their levels of industrialisation, are the first to suffer acutely from many of the present difficulties, but also because they are in a favourable position to work together towards solutions.

Integration of Social, Economic, and Scientific Policies

Economic growth has brought in its wake transformations that seem to have made obsolete some of the traditional concepts of economic policy. If, as we believe, growth and technological progress are two aspects of the same phenomenon, we can no longer consider technological progress as an independent variable. *Science and technology are an integral part of social and economic development, and we believe that this implies a much closer relationship between policies for science and technology and all socio-economic concerns and governmental responsibilities than has existed in the past.*

In the shorter term, we urge that *national and international economic agencies take greater account of scientific and technological factors in the implementation of their policies.*

In view of the fundamental role of technological innovation in economic growth, *OECD should continue and deepen its studies of innovation, its structural conditions, its economic motivations, and its scientific and technological components*, in order to assist governments in the development of science policies fully geared to the stimulation and guidance of socially acceptable technological progress.

Management of the economy has become difficult after a long period of rapid technological progress meaning also rapid economic growth. Economic theory as it exists today is no longer sufficient as a guide. We therefore recommend that *the Organisation launch a study on the working of money, fiscal, incomes and labour market policies in a society in which expanding knowledge, acting as a factor of production, increases the demand for both labour and capital by opening up numerous new technical possibilities while at the same time furthering the internationalisation of economic transactions and the formation of*

organised pressure groups. Such a study would be interdisciplinary, aimed at understanding the interactions of the economic, sociological, and technological aspects of the complex systems of modern industrial economies. It would enable the Organisation to refine and make more adequate its guidance on economic policy, where most countries are in disarray for the moment because technological expansion is changing the rules of the game.

Technological change may result in severe structural dislocations, resulting from disparities between industrial sectors, between geographic regions, and between different professions and occupations. *Both the Organisation and its Member countries should undertake studies on the influence of technological change on such disparities, on labour mobility, and on inflation.*

The Satisfaction of Collective Needs

The need for more broadly oriented technologies in all highly industrialized societies is evident and will increase as environmental problems become more acute and public awareness of the social costs of existing technological developments and their perspectives continue to grow. A country that developed such socially oriented technologies would be technologically "ahead", not only in terms of satisfying collective needs, but in terms of international economic competition. Such as reorientation of technology policy can therefore serve the smaller powers as a suitable strategy for overcoming the disadvantages accruing from the so-called "technological gap". *Governments of Member States should channel their technological policies into areas capable of producing alternative, socially oriented technologies, i.e., technologies capable of directly contributing to the solution of present infrastructural problems, of satisfying so far neglected collective needs, and finally of replacing existing environmentally deleterious technologies.*

In the social sector, adequate incentives are presently lacking in large part because there is no mechanism corresponding to the market to measure and reward performance; thus operations tend to be measured in terms of inputs rather than outputs. Many of the deficiencies are clearly technological in the classical sense, notably in air-traffic control, anti-pollution technology, ground transportation systems, especially the integration of different mores, postal services, health care, public housing. *The Organisation should consider extending its co-operative research activities into areas that relate primarily to productivity in public service sectors.*

How attitudes towards work, and the interrelationship between work and the rest of life, interact with technology and might modify future goals of technology are critical questions. They obviously relate closely to educational goals. *We recommend that the Organisation attempt to bring together what is known and what is being studied concerning these questions in the Member countries.*

The Assessment of Technological Progress

There is urgent need for a much more consistent rationale for the balancing of risks and benefits, not only in the sum total of risks and benefits, but also in their allocation among various segments of society.

This appropriate field of economic scholarship is in its infancy. It badly needs to be freed from its present emotional overtones, notably in relation to the environment. *The Organisation has a major responsibility to stimulate research in this field both on the methodological aspects of the problem and on the comparative study of practices, explicit and implicit, in the Member countries.*

Education as a Collective Need

Policy for education, especially higher education, has tended to be formulated on the assumption that students will automatically be distributed among fields of study in proportion to the career opportunities that will subsequently be open to them. However, in times of rapidly shifting social priorities, as at present, the time lag between entry into higher education and entry into employment often creates a serious mismatch between the output of the educational system and the career opportunities available. In fact, there is a very little understanding of the processes of adjustment of supply and demand for highly educated people. The Organisation has already done pioneering work in this area, but much more needs to be done.

Specifically, *we recommended that the Organisation's studies include the connection between excessive specialisation and the maladjustments between supply and demand, and ways in which greater flexibility can be introduced into the educational process in order to minimize these maladjustments and increase the adaptability of graduates in switching to new activities.* In this connection, the possibilities of periodic continuing education and mid-career "sabbaticals" for specialised personnel in industry and government as well as universities should be more extensively exploited. *We further recommend that, in planning for the development of higher-education institutions in the Member countries, effort should be aimed at greater differentiation in teaching approaches, organisation, and research orientation in order to accommodate a wider variety of cognitive styles, and to allow the economic and benefits of greater institutional specialisation.* Our recommendations are aimed at increasing the adaptability of graduates to career patterns that will be increasingly subject to change and reorientation in the future. Furthermore, any system of different educational tracks should allow for easy transfer of students between tracks even at fairly advanced stages of their careers.

The problem of matching education realistically to possible career opportunities poses a difficult problem for the democratization of advanced education and the assurance of equality of opportunity for every student, regardless of social and economic background, to compete for the most advanced training opportunities and the highest positions. *We recommend that, in all the Member countries, the financing of higher education be designed to assure the greatest possible openness in competition while not creating unrealistic expectations as to the number of places available at the highest levels.* Organisation studies on the economics of higher education should be focused on this specific problem.

Planning for Fundamental Research

All countries rely on the world output of fundamental research as a basis for new technological developments and for the rational management of technology. Fundamental research is thus an essential element in the total science and technology system, determining the quality of scientific and technical manpower and the standards for applied research and technology. Fundamental research thus has a considerable external economy; therefore *each Member country has an obligation to contribute to the world's pool of fundamental knowledge to the extent of its capability. The total level of fundamental research as a proportion of GNP in the Member countries should be maintained, if not increased, as a necessary condition for the continuation of social and technological progress in the future.* The present tendency, discernible in some Member countries, to demobilize research capacity is to be deplored.

The current shifts in priorities for technological and applied research should not imply less support of basic research to meet society's future needs. In order to contribute to social goals to the maximum degree in the long run, fundamental research must be provided with considerable autonomy in the determination of its own goals and programmes. Nevertheless, changing social goals do imply selective emphasis on new fields, particularly in the general understanding of complex interdependent systems and the sciences that deal with the natural environment from a systems viewpoint.

The emphasis on technological assessment and environmental management may require that, in the introduction of new technology, a considerably higher ratio of fundamental and exploratory applied research to development may be needed than in the past, because the forecasting of side-effects requires more fundamental understanding than is provided by the mere demonstration of technical feasibilities and commercial promise. *In the Member countries the future needs for technological and environmental assessment should be an important element in planning for the level and orientation of fundamental research and this planning should be done as far as possible in an international perspective.*

While a certain amount of national competition in science is a stimulus to excellence, at least the Member countries should be moving away from national competition, especially in big facilities, and towards a more international orientation; this is necessary in order to get the most value out of national scientific investments. In addition, international co-operation in large-scale basic science can set a model for co-operation in other areas and help in some of the international institution building that will be increasingly necessary for the international regulation of technology. This would include consultation by scientists of one country in evaluating research proposals or planning facilities and programmes in another. *International planning of major national facilities for research is therefore increasingly desirable, and it is recommended that OECD's Committee for Science Policy take the initiative in exploring and developing plans for greater co-operation*

and planning among Member countries in selected areas, especially those requiring large facilities or integrated systems of observation. Another useful undertaking would be the preparation of inventories of major fundamental research facilities and resources, including skilled manpower.

Multinational Firms and Technological Progress

The importance of multinational firms, and the benefits and problems they introduce for national socio-economic policies, warrant continuing study of the socio-economic and technological impact of such firms.

To a great extent, the multinational firm has made purely national policies in the economic and even the social sphere obsolescent, and there is therefore a growing need for agreement among the Member countries on the broad objectives of economic and social policy, and for concerting specific actions—harmonizing of corporation laws, patent laws, collective bargaining, social insurance, monopoly control etc. *The Organisation should undertake an intensive study of multinational firms in relation to their research programmes, national science policies, and their effects on the total course of innovation.* This was recommended by the last Ministerial Meeting on Science, and was not implemented. Such a study would inevitably raise the kinds of issues discussed in this report relative to multinational firms and the harmonization of national policies.

The Development of Sectoral Policies

We have indicated that science policy in the future is likely to require a blend of centralised and sectoral approaches. Sectoral policy is likely to become more important in many fields in which social needs suggest the requirement for a higher level of research and innovative activity. Many of these fields characteristically lie in the area of governmental responsibility, and are defined by high governmental investment, low growth of productivity, and only minor and fragmented research and development efforts. They include such sectors as health care, urban mass transportation, housing, land use, postal services, telecommunications, and solid-waste management. They also include activities that cut horizontally across many sectors, such as environmental protection, or the management and exploration of marine resources. There must be a determined effort to construct long-term forward-looking policies in such fields, in which market incentives to innovation and efficiency are often lacking. As a first step *we recommend that the Organisation undertake a series of comprehensive studies of several such sectors, their requirements for future research and development and for institutional innovation, and the possibilities they offer for the utilization of science and technology.* Such studies should take full advantage of the experience gained from similar studies or past practical efforts in the Member countries.

While advocating a sectoral approach in these cases, we are also convinced that, without central resources not committed to specific sectors, research programmes derived exclusively from sectoral needs

could easily become captive to short-term goals, day-to-day departmental policies, or overly narrow definitions of need. This would result in the exclusion of longer-term, and perhaps more fundamental, considerations as well as new concepts and definitions of the needs to be served. Accordingly, *we recommend that the Member countries, while encouraging the development of sectoral policies and their interactions, should ensure the central availability of a proportion of their research funds for longer-term investigations and studies, which will probe beyond the research programmes planned to meet well-formulated problems of departments and agencies responsible for particular sectors.*

International Aspects of Environmental Problems

The extent of the effects on international trade equilibrium of national actions on problems of the environment remains to be seen, and will require continuing assessment. Considerable self-restraint on the part of Member countries will be needed with respect to unilateral imposition of standards on the one hand and aggressive shifting of production to take advantage of tax standards on the other. This may prove to be a particularly touchy problem in relation to multinational companies unless the countries in which they operate adopt a concerted stance towards environmental regulations and standards. *The Organisation should keep this problem under surveillance, and this will require close co-ordination of economic, environmental, and science policy groups.*

In the consideration of issues and the application of standards relating to the environment, socio-economic and technical aspects cannot be considered separately. Although environmental-control policies might be primarily economic and legal in the short term, they cannot be formulated independently of a knowledge of future technological prospects and possibilities, for example, for pollution control, for less-polluting manufacturing processes, or for new power sources. *These considerations should be brought to the attention of the OECD Environment Committee with a view to ensuring that technological aspects are fully appreciated in the determination of tolerance levels or control mechanisms as well as in the design of improved technologies.*

Many environmental problems are global in nature and require international collaboration, both in assessing the extent of the problems and in taking remedial action. This is particularly true with respect to certain aspects of atmospheric pollution, the pollution of international waterways, and the contamination of the oceans by pesticides, fertilizers, petroleum products, and radioactive wastes. The technical character of these problems is often not fully understood, and monitoring systems are insufficient to determine what is happening. Since monitoring systems can become very expensive, there is an urgent need to develop a better technico-economic rationale for what to monitor, when and where, in relation to the time-urgency of various contaminant problems, the availability and prospects of the necessary technology, and the contribution of each monitor station to the global aassessment. *We therefore recommend that the Organization perform a central role in assembling authoritative information in this general*

field, serving as a central clearinghouse for compiling and evaluating such information, taking full advantage of the activities of other international groups, both official, and unofficial. Emphasis should be given to the preparation of authoritative policy-oriented status reports that can be readily understood by policy-makers.

The Social Sciences and Policy

The needs of the next decade for a more rational and socially acceptable approach to the application of technology require evaluation of various technological options. Better techniques are required to measure and understand the incidence of the costs and benefits of technology among the various social and economic participants involved; an important prerequisite for this will be adequate information on economic and social trends and impacts. Increasingly sophisticated social indicators should be evolved to monitor these trends and impacts, and to provide a system of "early warning" of growing imbalances, social disbenefits, dissatisfactions, and emerging social needs. *Major efforts should be stimulated to devise social indicators that will permit social components to be fully taken into account when evaluating cost and benefit in technological innovation.*

Social indicators, however, if they are to be fully useful, must be formulated in such a way that public and private administration can draw coherent and valid policy conclusions from them. Comparative studies between countries and the sharing of national insights and research results may have considerable advantages to offer in this regard. Parochial national biases and cultural traditions can often be better perceived through such a shared approach. For these reasons, *we recommend that the Organisation take the leadership in stimulating the development of the social sciences as tools of policy on a multinational basis, much as it has already done in the field of economic policy.*

In particular, the Organisation should ensure that social aspects are fully taken into account in the study of specific sectoral policies. Governments should include social scientists on central and sectoral policy councils, both to take advantage of new research inputs and to involve social science leaders in policy-making. Creation of effective career patterns in sociology and allied disciplines should be stimulated through better research funding and institution building. The Organisation, through its Education Committee, should assist restructuring of social science education, with special attention to producing social scientists able to translate knowledge into practice.

Science Policy and General Planning

The problems faced in government decisions are characterised by increasing interconnectedness of the various sectors of policy. Policies formulated for one sector of government responsibility may have important consequences, especially in the longer run, for the achievement of goals that lie in other spheres of responsibility. This interconnectedness of policy is incompatible with the purely vertical bureaucratic structures characteristic of most government organisations. Horizontal connections between these vertical structures at several different levels become necessary.

These considerations are especially relevant for science policy for two reasons. First, science and technology are inherently future-oriented and long-range activities and they cannot respond very effectively to goals that constantly change with political fashions or with shifts in public attention. Second, long-range planning for all the many interacting sectors of government responsibility demands a base of knowledge and data that can be acquired and interpreted only through science, including the social sciences. The acquisition of this knowledge itself requires planning beyond the time horizons of traditional political thinking. Thus science policy and general long-range social and economic planning are closely bound up with each other and require the same types of thinking and perspective. Policies for science, technology, education, public health, economic development, social welfare, and public services must be closely co-ordinated.

The need for effective co-ordination of policies, and for institutional arrangements capable of planning and assuring that co-ordination, leads us to *recommend creation of a governmental mechanism, operating under specific authorisation and full support of the head of government, with responsibility for investigation for long-range policy issues.* This would involve use of all available sources of information and expertise on science, technology, economic, and social trends, and would be closely related to science policy. The most important characteristic of this mechanism should be freedom—as far as possible in a politically accountable system—from the pressures of short-range problems within the time periods of political terms in office.

In order to bring the course of economic development, and particularly technological progress, into more satisfactory relationship to community needs and aspirations, *each government should establish, at Ministerial level or in a manner independent of the Executive, a special structure that would be responsible for anticipating the likely effects, threatening or beneficial, of technological initiatives and developments.* Such a structure would call upon the resources of industry, the government, and the universities in support of its operation, and would specifically seek assistance from all scientific disciplines.

In general, we feel that governments would benefit from exploration of an experimentation with their operating structures, in ways that would correspond to staff functions within industry that cut across operating departmental lines to achieve more effective horizontal co-ordination.

Science and Underdevelopment

The needs of the developing countries for science and technology are undoubtedly different from those of the developed countries. National science and technology policies within the developed countries should therefore be formulated with attention to the particular situation of those countriees. *We recommend that problems relating to science, technology, and underdevelopment be considered by Member countries as an integral part of their national science and technology policies.*

The Organization should make an inventory of the activities of its Member countries in science and technology in terms of their relevance

to underdevelopment. We furthermore believe that the developed countries ought, as a matter of conscious and explicit policy, to devote a certain fraction of their R & D activities to problems relevant to underdevelopment, and consider that a more rigorous inventory of present science activities should permit a more fruitful discussion than at present with respect to the controversial question of percentages of expenditure. This is a field in which co-operation between Member countries should be extensively developed. The inventory should be seen as a first step towards this. The Organisation should be requested to make any further studies required and formulate recommendations to Member governments in view of such co-operation. *Policies should be developed in two directions:*

1. *fostering in the less developed countries the development of indigenous capability in science and technology relevant to the socio-economic situation of those countries, and*
2. *formulating research programmes in favour of the developing countries in the laboratories of the advanced countries, as a part of science policy.*

It is of major concern to us that the recommendations made as from 1965 by the United Nations Advisory Committee on the Application of Science and Technology to development problems have had little effect. We suggest that discussions be held in the Organisation between Member countries participating in ECOSOC work to determine what steps should be taken to follow up the ECOSOC recommendations and, more specifically, those contained in The World Plan of Action (1971).

Only by creating institutions in the developing countries themselves does it seem possible, on the one hand, to mitigate the brain drain, and, on the other hand, to become sufficiently close to the particular prevailing economic and social environments to respond to their real research and development needs. *We recommend a pooling of advanced-country resources with this aim in view, and stress the value of centralising knowledge of these actions to ensure that, so far as possible, they fit in with an overall plan of international action for the installation of a network of centres of research and advanced studies in the developing countries.*

The developing countries need to draw as deeply as possible on the "stock" of scientific and technical knowledge existing throughout the world, to avoid duplication and, in some cases, to gain valuable time and to develop their own research activities on the basis of activities already existing or in process elsewhere. Some of the obstacles to transfer are deep-rooted in the economic and social conditions of the countries concerned and can be overcome only in the course of the economic development process itself. There are others, however, of a less fundamental nature, on which direct action is possible in cooperation with the advanced countries. *We believe the Organisation should examine the present situation with regard to the following:*

—aid in creating in the developing countries technical information-evaluation centres manned and organised by specialists capable of informing themselves of technological development abroad and of advising on the importation of technologies;

—fostering within the developing countries information banks of value for the specific needs of research on the Third World;

—the availability of training assignments and visits by specialists from the Third World to centres of excellence in their own disciplines in the advanced countries, to assure them of frequent consultation, without thereby inducing them to quit their own countries.

We recommend to governments that they organise formal arrangements permitting scientists and engineers from developed countries to spend periods of time in developing countries both to provide technical assistance and education, *in situ*, and to familiarise themselves with problems and conditions. This could be an important transfer mechanism.

MARCH, 1971.

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OFFICE OF SCIENCE AND TECHNOLOGY
WASHINGTON, D.C.

July 9, 1971

TO PSAC:

The attached paper is for discussion in connection with Item 4b on the PSAC agenda for July 20th.

David Beckler

ORGANISATION FOR ECONOMIC
CO-OPERATION AND DEVELOPMENT

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REPORT OF THE SECRETARY-GENERAL'S AD HOC GROUP ON NEW CONCEPTS OF SCIENCE POLICY

SCIENCE, GROWTH AND SOCIETY

A NEW PERSPECTIVE

80.285

This report was prepared in close collaboration with all members of the Science Policy Division, in particular Sheila Kelly, Gérard Bell, François Chesnais, Georges Ferné, Nicolas Jéquier and Jean-Jacques Salomon. The Secretariat wishes to express its thanks to those countries which received the members of the Group during the course of their study for their assistance in making contacts with institutions and personalities.

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PREFACE

1. Shortly after the creation of OECD in 1961, the Secretary General appointed a high-level group, under the chairmanship of Mr. Pierre Piganiol of France, to advise him on the nature and importance of science policy and the part the Organisation might play in its development. The report of this group, published in 1963 under the title "Science and the Policy of Governments", had considerable influence in the development of such policies in the Member countries. It pointed out that science policy has two facets: first there is the need to manage the scientific and technological resources of a country as a whole and, secondly, to understand more clearly the influence of new scientific and technical developments on other elements of government policies.

2. During the decade following the publication of that report, most Member countries created formal bodies to deal with national science policy, and many of them appointed ministers directly responsible for science and technology or both. The OECD has continued its interest in the field through its Committee for Science Policy, concentrating its attention, as have most Member countries, on issues of management and resource allocation and, as is appropriate to the Organisation, laying stress on the part played by science and technology in economic growth and development.

3. During this period there have been great changes in science and technology and their application in a wide variety of policy activities. Public funds for research and development grew steeply in almost all countries, but in some countries are now showing signs of leveling off or even decreasing. Today politicians and the public are more critical of demands for further expansion and are seriously concerned by actual and potential undesirable "side effects" of scientific and technological developments. High levels of economic achievement based on technological advances have produced widespread prosperity in the industrialised countries, but they have also altered man's environment and his working conditions, thus leading to what many regard as a deterioration of the quality of life, especially in the cities. This is resulting in a series of changing social demands, which will inevitably modify the goals to which scientific and technological efforts will be directed in the future.

4. These and other considerations led the Secretary General at the end of 1969, to set up a second ad hoc group on science policy, with the following mission:

(a) to identify the new problems and trends which are beginning to emerge;

(b) to analyse the resulting implications for society, and for the decision-making bodies in the field of science policy and in other fields.

5. This Science Policy Group has met on a number of occasions in Europe and the United States: its members and the Secretariat have held a series of discussions in Member countries with policy-makers and widely representative groups concerned with the impact of science and technology on society. Their report, presented here, attempts to assess the present situation, to identify trends and to suggest both to Member countries and the Organisation some of the changes envisaged.

6. The elaboration of a new type of science policy necessarily implies a critical examination of past and present activities. It is important to know how effective and comprehensive these policies have been, their main strengths and shortcomings, and how effectively they interact with other policies. The terms of reference of our Group go beyond these considerations, however, to suggest that such a new concept of science policy may well have to extend greatly the current boundaries of science policy as it is presently understood. It may be that the interactions of science policy with other policies will prove to be more important than its own internal mechanisms and objectives.

7. Since our explicit objective was to discuss science policy in the context of a changing social structure, we conceived it to be our first task to take into account development outside the traditional area of science policy. From the outset we decided to adopt a more comprehensive approach that would include goals that cannot be related exclusively either to the promotion of economic growth or to science for its own sake. The recent emphases on the protection of the natural environment and the quality of life are good examples of such goals, which will be pre-eminent in the 1970's. The Group considers science policy to be an integral factor in overall public policy; we believe that it cannot be rightly understood and directed unless its role in the framework of such a broader policy is made sufficiently clear.

8. Part I of this report will set out the assumptions made by the Science Policy Group concerning the essential issues surrounding national and international science policy in our time. Part II deals with the connections between economic growth, technology, and society. Part III attempts to evaluate the achievements, deficiencies, and limitations of science policy in the 1960's. Part IV suggests a new framework and new approaches to critical issues relating to effective functioning of science policy in the 1970's. In Part V, we present some recommendations to the OECD organisation and its Member countries.

PART I

ASSUMPTIONS CONCERNING SCIENCE, TECHNOLOGY, AND SOCIETY

9. Science and technology have been immensely successful for all OECD Member countries, and there seems to be no reason why they should not continue to be equally successful in the foreseeable future. In making this firm statement, members of the Group were fully aware that in recent years and in some sections of society this success is now regarded with some apprehension. There is today a certain emotional reaction against science and technology and some serious criticism of them. It is realised that the immense social benefits that have flowed from science and technology are sometimes accompanied by social disbenefits. Thus, policies concerned with science and technology in the next decade will have to take into account, much more explicitly than in the past, the benefits and disbenefits, actual and potential, that may result from the application of science or the deployment of technology.

10. A phenomenon of the last three decades has been that social demands, expressed by consumers through the market and by society collectively through the political process, have been remarkably constant in their requirement for particular kinds of scientific knowledge and of specialized training. Thus the form or mix of science and technology as developed in the education system and in industry has been moulded around these requirements. Hence, we now have a particular system of science and technology in the industrial countries, built up to satisfy social demands over the last three decades, which may not be suitable to the demands of society in the next decade.

11. In the last few years, however, there are signs that objectives are changing. Military, space, and nuclear energy programmes and other large public demands for science and technology are slackening off; although other aims can be seen to be developing, it is by no means clear what demands they will make on science and technology in the future either in quantity or in kind. Ultimately, of course, the system must adjust to suit whatever new demands emerge. But until these new social demands crystalize into more specific and better-defined objectives, the problems of science and technology policy in the next few years will centre on how to help the present system to adapt, while keeping it creative, productive, and efficient.

12. There are limitations, of course, in the rate at which the system of science and technology can change. The education system, which supplies the manpower for technology, probably has the longest time scale - of the order of 10 to 20 years. Thus although students can and do quickly adjust their demands for education according to their interpretation of employment

possibilities among other factors affecting their choices, the system supplying the education changes much more slowly. Similarly, the rate at which industry, the principal performer of technology, can change is also limited. The system of science and technology has naturally built up a considerable momentum over the past two or three decades and, whatever the change in demand placed upon it in the future, it will take several years to swing into new directions.

13. For one thing, we do not know exactly what the new aims of society will be, or how they will translate into specific objectives for science and technology. Failure of the system to respond to new social needs and demands could bring about a faltering and uncertainty from which it would take many years to recover. But excessive responsiveness to the short-term swings of social demand in all parts of the system could result in demoralization and collapse of the present delicately articulated system of science and technology.

14. Up to now science had remained a very well protected area in which decisions could be made without forcing too difficult conflicts. Continuous expansion has been an easy solution. With the profound changes in the established relationships between education, science, technology, and social and political demand, science policy will be faced with much more difficult decision-making. Even basic science will have to respond to needs for selective emphasis determined by the social, political, and industrial environment. To an increasing degree, science and technology are part of a single articulated system, no part of which can be entirely insulated from purposes outside itself, though obviously science can and should be more insulated than technology.

15. To many people participating democracy seems a solution to the problem of establishing social goals and assuring the responsiveness of science to them. This view is widely held among younger scientists. Yet the more groups and interests participating, the more likely are their goals and values to come into conflict or competition with each other. At the same time the growing complexity of society demands greater harmonization among the many separate decisions that are made. Thus participation and coherence often collide head-on, leading to paralysis of the decision-making process. Participation can also lead to conservative self-protection, or to superficially generous actions with unforeseen consequences harmful to the general welfare.

16. In traditional forms of organisation, bureaucracy has been the method for achieving consistency on any decisions. But bureaucracy often becomes rigid and unresponsive, elevating consistency to a place of unreasonable importance, at the cost of being unresponsive to changing needs, and neglectful of important interests and values. Organisations must provide a

process not for attaining rigidly prefixed objectives, but for developing, clarifying, and modifying objectives through bargaining and rational argument.

17. Science policy is generally conceived of as a deliberate and coherent basis for national decisions influencing the investment, institutional structure, creativity, and utilization of scientific research. Although no country has yet succeeded in implementing such a comprehensive approach, many are striving in that direction. In some instances, national science policies concentrate mainly on the research institutions producing new basic knowledge; in others they place greater emphasis on technology and its application to practical ends. In this report we are concerned with both scientific discovery and its application through technology, embracing both the natural and the social sciences, and hence, while we use the expression "science policy" for reasons of brevity, it should be taken throughout to mean policies for the natural sciences, the social sciences, and technology.

18. It is useful to distinguish science, producing new knowledge, from technology, embodying the application of knowledge in new ways of doing things useful to man. Nevertheless, science and technology form parts of a single system within national and international frameworks, interacting with other systems within those frameworks.

19. The boundaries of the science-technology system are difficult to define, not only because of its complexity but because it pervades all aspects of contemporary society: science and technology are one of society's main sources of innovation and dynamism. We can define science functionally as a set of institutions and mechanisms geared to the production, diffusion and application of knowledge. These institutions include the universities, the research laboratories of industry, mission-oriented research establishments of government and many private organisations. They do not, however, belong solely to science. Universities, for example, have a primarily educational function, and the laboratories of industry cannot be dissociated from the production of goods and services. The areas of intersection with other sub-systems as those of agriculture and health cannot be governed by policies determined for science alone, but represent zones of penetration of new knowledge and of scientific method into the total fabric of society.

20. At the centre of the system called science is the area of fundamental research, which is the reproductive mechanism of science and which is essential for the maintenance and continual revitalisation of the whole. The accumulation of knowledge and the construction of conceptual models of the natural world, including its inhabitants, remain the basic objective of scientific activity, and confirm the role of science as a fundamental

element of education and culture. As such, scientific research merits support in its own right, irrespective of its connections with education, economic growth, and social development. However, in pursuing these cultural aims, science also contributes in a very practical way to society either through education or through the understanding of man and nature leading to the possibility of modification or control.

Concerning Economic Growth

21. All the OECD governments are committed to a policy of economic growth, and expect that the growth in GNP during the 1970's will at least match that of the 1960's. Growth potential remains very high. But growth will be seen as a necessary but insufficient requirement for the OECD countries. As growth is taken more for granted by all segments of society, inflationary pressures will be increased as each organised group in society competes for a larger share of the GNP. This is likely to be a major economic issue of the decade, and it relates also to science policy through the fact that an important part of inflationary pressure arises within sectors of the economy in which the rate of growth of productivity is well below average. Since many of these lagging areas are services in the public sector, R & D that relates to these sectors must become a major problem - more important, perhaps, than that related to manufacture of material products. As private consumption grows, because of the interactions among parts of the economic system, it is probably necessary that the social infrastructure grow even more rapidly in order to maintain the quality of life and prevent dislocations in the economy. This is true of such areas as education, health care, housing, public transport, government services, and the preservation of the natural environment.

22. Modern industrial societies are accumulating requirements for investment in "social infrastructure" apart from the production of goods and services for private consumption. Deficiencies are accumulating in education, in health care, in housing for low income groups, in public transport, in government services, in public recreation, and in the protection of the natural environment against the rising tide of the wastes of industrial society. As personal income rises, each increment of material production produces more than proportional increments in the stresses on the environment and on the social structure itself. It is not economic growth by itself that generates these stresses, but rather economic growth defined exclusively in terms of private consumption or of the production of material goods.

23. Thus it is assumed that the principal policy problems of the near future will be concerned with assuring an evolution of developed societies that are freer of conflicts and contradictions. In traditional economics this means assuring a high level of employment while keeping domestic inflation and balance-of-payments

difficulties within bounds. In the relations between man and nature, policy will be concerned with the deterioration of the natural environment and with alleviating the social problems that derive from growing population and the concentration of population in large urban agglomerations.

24. In human relations, conflict and misunderstanding are evident between the generations, between labour and management, and between the academic, corporate, and government segments of society. These conflicts arise in part from genuine divergence of interests and values, in part because the very size of institutions and groups tends to restrict communication outside of particular groups, in spite of the increased ease of communication. This may lead to misunderstandings and misapprehensions, which could make more difficult the achievement of coherent, long-term policies.

25. There is a danger that the western world will see economic growth, technical dynamism, science and technology as sources of disharmony, and increasing attention will be devoted to seeking means of maintaining or re-establishing harmony in society, not through necessary change, but through vain attachment to the status quo.

26. The general public, however, will be slow to accept the full implications of the goal of harmony of man and his environment. It does not yet recognize the costs - both in economic terms and in terms of limitations on the freedom of individual choice - and it will be only slowly educated to understand and accept them.

27. We assume, however, that the public and the government will remain willing to use large technical resources to achieve the goals of society when there is a sufficient consensus on the need and the objectives are sufficiently clear. While there will doubtless be much more caution in embarking on new weapons and space projects, new resources will be required by projects related to air traffic control, global weather forecasting, water development, nuclear power, or other areas related to the management of resources and of the environment. Lack of widespread consensus on needs may be one of the reasons for the present lag of support for science.

Concerning Goals and Problems of Science Policy

28. The emphasis on harmony also implies a reorientation of science, and there will be real problems to avoid damaging its integrity and vitality in the transition phase. New social concerns raise issues with different linkages to science and also different linkages within science. For example, science has received social support over the last 15 years primarily

because of its role as a source of technology, but in the future it will be equally important in providing a wider intellectual base for the control and orientation of technology - a more subtle and more complicated role. Similarly, the new problems call for much stronger linkages between the natural and social sciences or behavioural sciences. For example, in the field of health, the focus of attention is shifting from the biology of individual diseases to socio-medical pathologies such as drug addiction, alcoholism, and environmentally induced diseases. In education, the development of new techniques of learning may call for closer linkages between engineering and the behavioural sciences.

29. Science will be important not only for generating specific technologies to prevent or reverse the deterioration of the environment, but also for assuring better use of society's resources through better decisions about technology. The emphasis will shift from establishing feasibility to choosing the most desirable developments out of the rich menu of alternatives provided by science, and it will fall partly to science to develop the criteria of selection and to illuminate the implications for various social values of alternative technological choices.

30. In science policy, considerations of national security, the use of technology as an instrument of political prestige, and the arms race in strategic weapons systems may well decline in importance and in public and political attention. Spending for weapons throughout the world will probably remain at a high level, but decline as a percentage of total production of goods and services. Many not too improbable political events could abruptly change this situation during the decade, but it does appear that all the OECD governments are now acting as though the assumption were correct. Science and technology for national security purposes will continue to play a very important role in science policy and will affect the direction of innovation even in the civilian sector, but to a somewhat declining degree. Much as many deplore such a slow evolution away from existing priorities we believe it to be the most probable trend.

31. Many aspects of developed societies are approaching a condition that may be described as the precursor of saturation, in the sense that things cannot go on growing much longer in some lines without reaching fairly fundamental limits. Indications of saturation are present in total population, pollution of the environment, in the size of urban conglomerations, in traffic, in information overload impinging on the individual, even in higher education and, perhaps in the view of some people, the production of new knowledge. This does not mean that growth will stop in the next decade, or even that the time limits for growth in the future can now be foreseen in every instance, but only that a declining rate of growth is foreseeable within the

lifetime of people now alive. In a society now accustomed to growth in almost all its aspects during the last 300 years, this is something quite new, something that will require considerable adjustment. The general perception of saturation will appear only gradually.

32. The composition of output is likely to shift from the production of private goods for the market to the production of "public goods", i.e., goods and services purchased collectively or supplied by the public sector. Actually, the distinction between public and private is not a sharp one. The term includes goods and services that are supplied by the public sector, at least in part, although in principle they can be valued on the market by individuals - e.g., education, health care, recreation - and that can be enjoyed only collectively - e.g., clean air and water, parks, public recreation facilities, civic order, and fire protection. In recent years there has been a steady shift of goods and services once thought of as private into the public sector. Among the best examples are health care and higher education. Housing and urban mass transport are other examples of services that benefit individuals but are believed to have sufficient "external benefit" for society to be publicly subsidized. But productivity in almost all these areas has lagged behind productivity in the manufacture of capital and consumption goods for the private market. Thus science policy will be increasingly concerned with improving productivity in these fields, and with establishing objective criteria of performance. Governments will also be concerned with measures to influence private enterprise more directly in the composition of its output and in the impact of its products on the condition of society, personal health and safety, and on the natural environment. To the extent that policy in this area depends on systematic knowledge and inquiry, this will be an important new element of science policy.

Concerning the Scope of Science Policy

33. Despite the growing importance of the public sector and of government intervention to influence the composition of private output and investment for social benefit, there will still be a desire to rely on market or quasi-market mechanisms. The predominant method of government intervention will be by influencing the pattern of demand by structuring incentives through taxation, regulation, and other means. There will be increasing concern with how the economic success of the firm and its desired contribution to the welfare of society can be harmonized through modification of the ground rules under which the firm operates, so that the private market can be utilized to reward behaviour that is considered in the interests of society, or penalize behaviour that has undesirable social costs, more or less automatically.

34. Problems arising from the impact of technology will become increasingly international in scope and will require vigorous evolution of international mechanisms to cope with them. Such mechanisms exist now in rudimentary form and, given sufficiently rapid evolution, might serve the needs. Whether this evolution will actually occur without much bolder political initiative than is now visible is questionable. The management and protection of the global environment will require constraints on national sovereignties for which there is little precedent except in very narrow areas. While a great many environmental problems today are local or regional in nature, they will assume global proportions in the next 20 years, and hence will have to be attacked on a globally concerted basis.

35. In addition, there may be growing concern over the market allocation and use of the world's raw materials, particularly between the developed and the underdeveloped regions. Questions will increasingly be raised regarding the equity of the allocation of benefits and costs of technological progress, not only among segments of a national society but also between nations at different levels of development. To what extent is inappropriate technology of advanced nations being thrust upon underdeveloped societies to the detriment of their social structure and their real development needs? These are not simple issues, for in fact predicted raw material shortages have not developed, and many primary products are failing in relative price, and the costs and benefits of advanced technologies to underdeveloped societies are hard to identify.

36. There is a growing awareness of the gaps between the rich and poor countries, and this will become increasingly important politically during the decade, if only because of the spread of modern communications, transportation, and education. There are signs that when developing countries have reached a certain stage in their progress towards higher standards of living, they can begin to catch up with the richer nations, but this also tends to open up a wider gap within the group of less developed countries, a gap that may have more serious political repercussions than the more spectacular gaps between very rich and very poor. How to provide technical and economic assistance while allaying fears of political domination and loss of control of the direction of growth and of the allocation of benefits within local economies, will become an increasingly urgent problem.

37. The trend to internationalisation of business enterprise will continue to increase, and will make it increasingly difficult for national governments to regulate their own economies without restrictions, which have difficult political repercussions internationally. Only if the countries that are hosts to international firms carefully concert their economic and social policies will it be possible for them to live with international business. If large banks and firms can lend, borrow, or invest abroad on a

sufficiently large scale, they can influence the patterns of trade, production, employment, and international payments in ways that can in fact nullify national government policies. Increased sense of social responsibility among multinational firms and the co-ordination of national policies towards those firms will require the progressive internationalization of decision-making with respect to economic policy, to the introduction and regulation of technology, and even to global management of environmental problems.

In conclusion

38. We have assumed that the trends discussed above will form the background for the evolution of science policy in the future. They are primarily extropolations of existing or emerging trends in policy or in the general climate of opinion. Like all such extrapolations, they are subject to many uncertainties. For example, the international military and political equilibrium is sufficiently precarious so that a new technological trend or a new political development could drastically alter the present trend towards declining emphasis of the use of science and technology for military and prestige purposes. The world-wide culture of educated youth, which is deeply concerned with ecological perspectives and is increasingly anti-materialistic, egalitarian, anti-meritocratic, and anti-bureaucratic, could conceivably even adopt anti-rational views and could become much more influential in the next decade than our extrapolations suggest, especially if established methods fail to bring significant improvement. The failure of evolution of international decision-making mechanisms to cope with multinational firms, the internationalization of capital, and global management of environmental problems could create a crisis that would lead to retreats into protectionism, nationalism, and economic parochialism. The reaction against science could lead to retardation of scientific progress to the point where the world lacked the intellectual tools to cope with the complexity it has created. While all these developments are possible we do not see them as the most likely ones, and in any case not the ones for which an international organization like the OECD realistically should be planning.

PART II

ECONOMIC GROWTH, TECHNOLOGY, AND SOCIETY

39. On 22nd May 1970 the OECD Council, on the occasion of its Ministerial meeting, issued a communiqué containing the following passage:

> "Ministers stressed that growth is not an end in itself, but rather an instrument for creating better conditions of life. Increased attention must be given to the qualitative aspects of growth and to the formulation of policies with respect to the broad economic and social choices involved in the allocation of growing resources. Ministers emphasized that an important task of the OECD will be to assist Governments in these aims."

40. Authoritative observers do not seem to have given this statement the full attention it merits; yet it marks both the end of one era and the faltering start of another. It seems to reflect the growing concern about harmony in society. Could those who, more than a century ago, dreamed of a future society in which abundance would finally reconcile man with himself and with nature, and who still have so much influence on various schools of social thought, ever have imagined that the dawn of this era would be greeted, not by shouts of triumph, but with apprehension ?

41. After a decade of unprecedented growth (50 per cent to 60 per cent growth in real terms in the OECD countries as a whole for the period 1961-1970), the OECD "forecasts that, provided adequate policies are followed, this trend should go on gathering momentum over the coming decade and should allow a 60 per cent to 70 per cent growth of GNP, in real terms, for the OECD countries as a whole, or in other words, should double by 1980 the average income per head of population as it stood in 1960". Agreed that this in itself may not be "abundance", who would be bold enough to define such a relative concept? By any reckoning, it is a degree of wealth with no parallel, either in past history or in any other part of the globe.

42. Yet, in spite of these achievements, concern about the future is widespread in our societies. Faith in economic growth has been replaced by a feeling of unease in the face of the prospects opened up by it and has been shown to be insufficient in itself to respond to the aspirations of mankind for a better way of life. What is more, far from bringing only benefits, it is accompanied by more or less traumatic effects, less and less acceptable to large sectors of public opinion. Finally, the transformations that it engenders throughout the whole economic system increasingly reduce the effectiveness of traditional

mechanisms devised to cope with the management of that system. Thus it is, in a sense, that by its very success the economic approach has proved its limitations. We are therefore concerned here with formulating appropriate means to manage growth, thereby aiding governments in the improvement of their policies for action. But before any policy whatsoever is proposed, the nature of the problems posed by "the very success" of economic development must be better appreciated.

Growth and Unsatisfied Needs

43. As production increases, and with it the standard of living measured in terms of per capita GNP, the gap between the actual condition of life of the average individual and his horizon of satisfaction appears to be increasing. This gap between reality and expectation is especially acute at the lower end of the economic and social scale, despite absolute improvement in standards.

44. Furthermore, a part of the increase in per capita GNP is simply absorbed in changing life styles, so that what were once luxuries become necessities required, for example, for access to remunerative work or to other basic activities. For instance, among the residents of central cities, the deterioration of urban mass transportation may represent a more serious decrease in living standard than the ability to purchase a television set represents an increase.

45. Thus, per capita GNP may be a poor measuring instrument for standard of living and even poorer for human satisfaction. National accounting systems provide a good description of economic flows, and of their extent and direction, but they cloak much of the reality of the growth process, which is expressed more through transformations in the quality and mix of accessible goods and services than through quantity.

46. Furthermore, when most of the members of society are permanently living near the margin of subsistence, needs are easy to identify, indisputable, and for all practical purposes unalterable, though perhaps variable as to quantity. Under these circumstances the market - a complicated and sensitive mechanism evolved over the course of centuries - is in theory a good instrument for the allocation of productive resources. It gives expression to the range and degree of intensity of a variety of felt needs, and generates signals that direct productive resources to the meeting of these needs.

47. However, once the stage of relieving economic scarcity for the majority of the members of society is passed, the accuracy and sensitivity of the market mechanism as an indicator of the aspirations of society can be called in question. The transforma-

tions generated by economic growth in the market sector of the economy have given birth to a range of new needs that are not readily expressible as market demand. These are collective needs - essentially indivisible benefits enjoyed in some measure by all members of society whether they pay for them or not, e.g., clean air and water, aesthetically satisfying urban surroundings, the amenities of nature.

48. In addition, there is a trend towards supplying certain types of needs as a matter of right to all citizens, even though these needs were formerly treated as goods or services to be sold on the market. Examples are universal education, health care, parks and recreation areas, public housing, social welfare services, and the preservation of civil order. When most of society is reasonably affluent, the social disbenefits resulting from the persistence of illiteracy, disease, substandard housing, social disintegration, and malnutrition, among a small minority, make it necessary for society as a whole to provide those minimum standards that the signals from the market have failed to call forth. This is not only a matter of social justice; it is actually in the self-interest of all members of society.

49. We now find ourselves in a situation in which the marginal utility of the necessities of life is decreasing for the great majority, while the marginal utility of collective needs is increasing. At the same time these collective needs are becoming more difficult vor governments to anticipate and satisfy. In fact, the very success of the market system in satisfying private needs for both necessities and luxuries creates additional collective needs much faster than proportionately to the growth of the market economy. The side effects of economic growth are often of a highly non-linear character, appearing rapidly, and creating a new collective need for their abatement and control, often with almost a threshold effect. These thresholds are partly physical; for example, photochemical smog from motor-car exhausts appears only when the concentration of exhaust products reaches a critical point. Other thresholds are simply thresholds of public perception, which find political expression only when a certain segment of the population is affected, as in the case of jet-aircraft noise.

50. With or without regard to the ability of public authorities to predict and satisfy collective needs, we are bound to recognize that it is man's whole existence and life style that are at stake in the last analysis. We are less than two generations away from the time when the human population must reach a new equilibrium in the distribution of its members and in relation to its environment. This will modify the age composition of populations and call for profound changes in life style, in values and in the structure of institutions. Moreover, as their material wants are satisfied, growing numbers of people will look for other avenues of self-fulfilment - for aesthetic

and intellectual expression, for more psychologically rewarding work, for more human inter-personal relationships, for activities that confirm their own sense of self-worth and uniqueness as human beings.

51. If we admit that the realization of the aspirations of society still depends to a major extent on additional economic resources that can be provided only by growth, and that growth demands further improvements in the level of efficiency and productivity, we must also recognize that increasingly man cannot live by bread alone, and that the use of the economic system to contribute to human hapiness rather than merely material satisfaction presents a challenge to the imagination that the developed countries must begin to take up seriously during the coming decade. This challenge becomes the more serious and perplexing when we realize that more than two-thirds of the world's population will still be living barely above the margin of subsistence, and this fact alone will continually challenge the consciences and hence the self-valuations of the more fortunate third.

The Byproducts of Growth

52. Growth is not a simple uniform process. A continuous qualitative change in the internal structure of the system accompanies the general expansion. This change affects not only the pattern of products and therefore the production sector and, consequently, the way of life of the people, but also the characteristic relations of social groups, regions, and nations, and even the relations of man with nature.

53. These processes of change and the shifts of resources between sectors and uses which accompany them, are not merely symptons of the growth process, but an essential part of it. Schumpeter says "Growth is a process of creative destruction". This is borne out by the analysis of centuries of economic development, and thus does not apply solely to the situation over the last 25 years. What is new, on the other hand, is that the transformations generated by growth are no longer limited, as they were in the past, to sharply circumscribed sectors of the economy and are no longer spread over sufficiently long periods to deaden the shock of change. Practically all sectors are today exposed to transformations so intense and rapid that several major upheavals may sometimes be recorded in a single lifetime.

54. The concentration of business enterprises, the disappearance of uneconomic firms, the decline of regions that are too specialised or too remote from the new trade routes, the continuous modification of techniques and the consequent obsolescence of knowledge, the rapid devaluation of skills, sometimes leading to premature retirement, the depreciation of the values of long experience compared with the new knowledge of the young

(already virtually outdated by the generation on their heels): all these features, which are the expression and the condition of growth, cannot fail to entail serious social upheavals.

55. Some steps have been taken to try to attenuate the ill-effects of these "byproducts" of growth, in land-use planning policies, retraining policies, even agricultural policies. These have not been entirely without effect, but they can hardly be said to have seriously and effectively counter-balanced the social costs that may in the long run seem to be a high price to pay for the benefits reaped in return. Such a situation engenders, in particular, a general feeling of insecurity and instability, which may lie at the root of certain social behaviour; the sacrifice of the individual as producer to the individual consumer, which is one of the consequences of the type and form of growth we know today, is reflected in the last analysis by a "personality split", the character and effects of which have not yet been measured.

56. It is by no means certain that, unless a prompt remedy is found for the situation described, the very driving force of growth itself will not, in the long run, be compromised.

57. Growth, then, is inevitably accompanied by the obsolescence of certain activities. The result is that certain regions and certain social groups seem to be "rejects", since, for instance, the fruits of growth are unevenly divided among the social groups and regions of the countries that participate in the whole growth process.

58. We must consider specifically the case of the developing countries, though the problem there is essentially no different in character. True, the growth rates recorded in many developing countries are encouraging. But, partly because of rapid population growth, the income gap between the poorest of these countries, representing half of mankind, and the rest of the world is widening. In a world bound closely together by the speed of information and travel, this fact is inevitably disturbing. It tends to maintain a perpetual climate of dissatisfaction, and may even lead to desperate acts on the part of people who see the equalisation of their incomes with those of the rich peoples increasingly as a mirage.

59. The evident fact that the growth of the industrialised peoples, and especially its tempo and technical modes, is at the same time the motive force behind the progress recorded by the developing countries and the cause of the latent dissatisfaction of the peoples of the Third World is only apparently a paradox. It demonstrates the complexity of the problem, the difficulty of finding simple solutions, and the urgency of action. In any event, purely economic solutions are insufficient. As economists themselves recognise, it is important rapidly to forge instruments

of analysis and action commensurate with the challenge facing us.

60. A recent OECD report points out that "the growth process itself generates side effects which may be socially undesirable or, in some cases, actually dangerous; urban congestion, the decay of city centres, pollution of the environment are obvious examples"(1). Here we are faced more obviously than in the previous problems (and that is why we raise it here) with the cumulative effects resulting from technical choices and mass production, themselves the result of adopting efficiency and economy as the sole criteria of desirable growth.

61. The public conscience is now alive to these consequences, today generically labeled "environmental problems". Scarcely a day goes by on which they are not broached by the press from one angle or another. Governments and international organisations are giving them active attention. The Organisation, which did pioneer work in this field and gave a powerful impetus to the public recognition of the gravity of the issues, has recently created an Environment Committee, which will enable it to work towards finding necessary solutions. There is therefore no point in reviewing the situation again in this report. However, we shall indicate below the contributions that science policies can make to the general effort to develop effective approaches. It is indeed clear that economic analyses and economic policies are not in themselves enough to cope with this fundamental problem. This is true not only of the detection and evaluation of causes, but of the remedies to be applied.

62. In the face of the results achieved by 25 years of uninterrupted economic growth, and of the technical prowess it has permitted, as exemplified by the voyage to the moon, the man in the street naturally tends to think that vigorous effort and judicious allocation of resources are enough to put us on the right lines towards an all-sufficient solution. This does not seem to be true; the destruction of the environment, the disequilibrium of the ecosystem, are not fortuitous events; they are linked with the whole course of our civilisation. The transition from a vectored economy - running in a straight line from the exploitation of non-renewable resources to waste products - to an economy of recycling cannot be effected without structural upheavals. These will not all be technical or economic in character, but they will have a direct impact upon standards and ways of life.

Growth and Control of the Economy

63. The need to approach the question of the development of societies more comprehensively going beyond exclusively economic considerations, is clearly demonstrated by the difficulties encountered in attempts to manage the whole growth process by

(1) "The Growth of Output in OECD Countries, 1960-1980". Ch. 5, OECD, Paris, 1970.

application of "classical" economies. Most countries have not succeeded in keeping their economies consistently on a balanced growth path. If, at the beginning of the 1960's, the essential requirement was to maintain sufficient pressure of demand, it seems today to be rather to maintain it within limits compatible with an acceptable rise in prices.

64. What is particularly novel and disturbing today is that the classic measures used to master the inflationary process seem to operate more slowly and less reliably than in the past, as was brought out by a recent OECD report (1). The time therefore seems to have come to review economic policy mechanisms in the light of known transformations. We confine ourselves to expressing our views on some of the most important difficulties concerning economic policies.

65. Fiscal policy appears to work somewhat more slowly in high-income societies than it did when income levels were generally lower. If people are normally saving part of their incomes and have some accumulated savings, they may react to tax increases by reducing savings rather than by reducing consumption, at least for short periods. This has probably happened in some countries in recent years, though it is difficult to say to what extent. The question ought to be studied, since it can be expected to become more important in the years ahead.

66. Monetary policies, too, are becoming more difficult. The comparative importance of high or low rates of interest has greatly diminished, partly because of progressive income taxation, and partly because expectation of continued inflation has now been built into the system. If an investor has to pay even 10 per cent interest on borrowed money, not only will the interest paid reduce his income tax more than if the rate were lower, but also he is likely to consider that the rate may be quite as high next year while the costs of the investments will probably be higher. Moreover, the room for manoeuvre concerning interest rates is often very narrow, because large-scale capital outflow or inflow may result if rates are too low or too high compared with those of other countries. While the effects of interest-rate changes are becoming very uncertain, one can be more sure of the effectiveness of measures to reduce or increase the liquidity of the national banking system. Even here, though, international capital movements can largely counteract national policies unless restrictions are introduced, which, from other points of view, is normally undesirable. Furthermore, large companies can often make themselves fairly independent of national credit policy.

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(1) op. cit.

67. Inflation is not always, and seldom exclusively, due to excess demand. So-called cost-push inflation is rather due to increases in wages and other cost elements that are increased by simple decision. Similarly, prices can be kept high or can be increased by decisions taken by firms or groups of firms with strong market power positions. Such decisions are, of course, particularly easy to take when demand is at a high level. In a number of cases, however, inflation has continued even after measures have been taken to reduce demand, and there may be an increasing built-in inclination for this to happen.

68. This is why incomes policy has become an important issue in recent years. It has, however, proved very difficult, which is not surprising in view of the competition between the various social groups. It is particularly difficult to make sure that non-wage incomes are included in the efforts to restrict the general level of incomes, measured in money. Therefore, this problem is closely linked to the problem of labour/management relations. It is also linked to the problem of monopoly control.

69. Should integration of business, leading to very large enterprises, always be favoured because it is supposed to mean more efficiency? Or should it sometimes be regulated because it may give the firms a strong market power? In either case, how can one control the incomes of very large firms, operating in many countries, for reasons of taxation and incomes policy? How can monopoly control be effective in such cases when an individual government has access to information only about operations in its own country?

70. Far too little is known about these problems. It seems likely that co-operation between the authorities in various countries as well as harmonisation of legislation will be needed as multinational companies grow in size and numbers. But it should be developed on the basis of careful analysis of the facts and of the implications of measures that might be taken.

71. Not enough is known about the complete technico-economic processes that are transforming society to give simple answers to the many problems raised in the preceding paragraphs. The science of economics, despite all the refinements it has undergone in this century, has not been able to give policy-makers the kinds of advice they need. A more comprehensive approach is required, and it should be one of the tasks of future science policy to encourage thorough study of the interactions between what we traditionally called economic factors and the structural changes due to the extraordinary advances of science and technology in current history.

72. A few remarks are needed to indicate the nature of the problems to be studied. Knowledge produced by science and developments in technology constitutes factors of production.

It increases the productivity of labour and capital and opens up a wide range of new possibilities for the use of both man and machinery, with a consequent rapid obsolescence of capital equipment and labour skills. Thus they tend to increase the demand for labour and capital, so that wages and interest rates are pushed upwards simultaneously. This demand is difficult to control because, as mentioned above, both consumers and large firms are becoming more independent of governments. In fact, knowledge favours the internationalization of business because more is known about all countries and because R & D per unit becomes cheaper as scales of operations increase. It also favours the organisation of all kinds of pressure groups, trying to get larger shares of national income. Finally, it increases the efficiency of advertising and of political propaganda and thus increases demand in various ways. It should be added that, since the overwhelming part of the new knowledge is produced in the rich countries, it promotes the economic growth of those countries, before it can spread to the poor nations and be adapted to their special situations.

73. It seems that to master all these consequences of knowledge more knowledge is needed. It is urgent that we get a clearer picture than we have today of the complete system of interactions between technical, economic, psychological, and sociological factors that is transforming our societies almost beyond recognition. Thus, an adequate science policy is one of the preconditions for more sophisticated economic policies.

74. In the past, economic theory has often treated technological progress as an independent or exogenous variable, apart from the process of economic growth. This is not a proper separation, however, because the rate and direction of innovative activity are so heavily conditioned by the volume and composition of demand, and by the distribution of purchasing power among individuals and institutions (including government). At the same time, innovation is also influenced by the nature of the technological process itself and the linkages between technologies and between new knowledge and application. Thus innovation begun to meet one demand may end by satisfying a quite different and originally unanticipated demand.

75. Research or development undertaken for one purpose in response to a perceived social need may reveal possibilities for meeting other social needs. This can come about either through new scientific discoveries, the uncovering of new techniques, or the horizontal transfer of a technique or process perfected to meet one demand to satisfy new demands. Horizontal transfer is especially important in the capital-goods market. Once a product or process is developed, the entrepreneur has strong incentives to find other applications for it in order to expand his markets, and this process can by itself contribute powerfully to economic growth. Development costs and the costs of probing the market

are often amortized in a very expensive and specialized market, and the resulting product - with the initial cost of innovation amortized - can then be diffused in a much wider and more diversified market. A prime example of this is the diffusing of computer technology from the military-space market to the business-data-processing market.

76. Another important consequence of the interaction between the innovation process and the expression of social need through market purchasing power is product differentiation. The frequently cited example is the motor-car, whose main social function is personal transport, but which becomes highly differentiated to satisfy a whole spectrum of secondary and more or less conscious desires of the car owner - as a status symbol, a release of the aggressive impulse, etc.

77. Technological progress, however, in meeting needs expressed through effective purchasing power, often disregards needs that do not give adequate signals through the market. In the motor-car case, for example, the requirements for free traffic circulation in the centres of towns or for clean air are not adequately expressed through the market, which consequently fails to produce technology to satisfy these requirements. The motor-car example illustrates the fact that market demand often leads to excessive innovation in some areas (as in over-differentiation of products) and insufficient innovation in others, with results that are familiar to us in the deterioration of the environment, the exhaustion of natural resources, etc. Thus, although the individual consumer benefits through access to a larger quantity of goods and services, it may be at the expense of deterioration of his general way of life, because of attempts to satisfy the needs of too many consumers. What is in the individual interest of each consumer is not in the collective interest of all consumers.

78. This phenomenon has led to increasing dissatisfaction with the instruments of economic accounting, if not for the short-term management of the economy, then for its long-term development and the measurement of public satisfaction. This undoubtedly explains the great interest in social indicators, which are regarded as means of detecting and quantifying needs not reflected by the market. These indicators are by themselves insufficient if they do not help us modify the direction of technological progress. This lies at the heart of the problem of "the quality of life", which seems destined to be the slogan of the 1970's, as economic growth was of the 1960's.

79. It is encouraging that considerable efforts to work out social indicators have been made by various bodies, such as the U.N. Social Development Institute, and several governments including France, the Netherlands, Japan, and the United States. Recently, work has been initiated within the OECD towards the development of such indicators. Although GNP and other national

accounting concepts are under severe criticism we should remember that these concepts, developed during the 1930's and applied after World War II, have contributed to the improved management of economic policy, and we should look toward a similar development in social indicators that are now just coming into use.

80. The imperative for the coming decade is, then, the management and orientation of technological progress, which condition the pace and content of economic growth. New machinery must be set up and new policies formulated. Is science policy, as we knew it during the 1960's, the right instrument for this purpose? Or should it be given a new content? In any case, science policy must be much more broadly conceived than in the past, as we shall elaborate in the subsequent parts of this report.

PART III

SOME LESSONS OF THE SIXTIES

81. It was only after the Second World War that science policies, although not previously unheard of, were deliberately and effectively shaped in many countries. Science and technology then emerged as the dominant forces shaping the development of society; the relations between science and the state became institutionalised; influencing government policy, science and technology became affairs of state. The term "policy", wherever it is applied, connotes will and coherence. "Science policy", in fact, embraces a somewhat disparate set of problems and issues.

82. In the first place, science policy means policy for the development of technology, as well as policy for science as ordinarily understood. It is concerned with the allocation of resources for sceintific research and technological development. It includes government encouragement of science and technology as the roots of strategy for industrial development and economic growth; but it also includes the use of science in connection with problems of the public sector. Because of the close association of basic research with higher education, this aspect of science policy is difficult to separate from overall educational policy and from technical manpower policy.

83. But science policy does not comprise only policy for science - that is, for the creation of an environment in which science can flourish and choices can be made among scientific and technological projects and fields; it also comprises science for policy - affecting the ways in which scientific and technical considerations bear on important political decisions and policy choices in areas that are not themselves mainly scientific, such as foreign affairs of urban planning. Indeed, some observers have even questioned whether it makes sense to conceive of science policy as a distinct and separate area of policy. Nevertheless, science, including the social sciences, penetrates deeply into almost every aspect of the government function, as indicated by the growing percentage of technical specialists in the upper levels of the civil service. It requires consideration in its entirety as a set of means to other goals, having some coherence within itself across the functions that it serves.

84. In most industrialised countries, government intervention was reflected, up to 1967, in the increasing injection of resources into research activities, and by a more or less organised effort to orient research towards certain national goals. The increase in resources was so rapid and so continuous that people were not far from regarding it as an inevitable phenomenon, virtually outside the area of political choice.

The effort was so deliberate and so general that the magnitude of the investments and the nature of the choices made seemed in themselves a sufficient guarantee of their consistency, if not of their rationality. This period of abundance for scientific research led to an unprecedented development in national potential in scientists, laboratories, and equipment and produced a flowering of discovery and technological accomplishment. But the period that followed, during which the rate of growth of appropriations leveled off (and budget restrictions were introduced in some countries) not only confirmed that an exponential growth could not continue indefinitely but also revealed a number of problems previously masked by abundance of resources.

85. Science policy has been one of the instruments for the expansion of technological progress, but this instrument has been none the less rudimentary both in the use made of it and in the ends to which it has been directed. If science policy is entering a period of uncertainty and reassessment, it is not so much due to failings in science policy itself as to the fact that government policy in general and the goals of society, after a long period of consensus, are themselves passing through a period of uncertainty and conflict.

86. Thus, science policy is in disarray because society itself is in disarray, partly for the very reason that the power of modern science has enabled society to reach goals that were formerly only vague aspirations, but whose achievement has revealed their shallowness or has created expectations that outrun even the possibilities of modern technology or the economic resources available from growth. It is against this background that the limitations and relative failures of science policies during the last decade can be understood most clearly. A crisis of growth and a crisis of the linkage of science policy to social aspirations seem to be two closely related aspects of the same problem: the aim of science policy cannot be solely the expansion of science and technology but must include the management and direction of technological progress for the service of other ends.

Research Policies or Science Policies?

87. During the postwar era one can distinguish three phases of the overall political climate in which science has operated. The first was the longest and continued, with some fluctuations, from the end of the war to the beginning of the 1960's. It was characterised by high public faith in the efficacy of science, and high political prestige of scientists, chiefly in the countries that were victors in the war, and above all in the United Kingdom and the United States. During this period national security considerations and the evolution of the cold war dominated the formulation of national science policies. The science of physics held the centre of the stage in the development

of postwar science as a whole, and the views and style of physicists held sway in the institutions of science and the councils of national science policy.

88. The second phase extended from about 1961 to 1967 and was characterised by the gradual emergence of economists and systems analysts as significant influences in science policy. Government attitudes towards science and technology emerged from the euphoric phase into an era in which rational resource allocation and the role of science and technology in economic growth replaced the cold war and technological competition as central issues. Science began to be related to a much wider range of national problems, beginning with health and extending into the social and economic domain generally. Even the national security aspects of science were viewed partly in terms of their possible "spill-over" into economic and social development. This was the era of controversy over the existence of a "technological gap", the process of transfer of science and technology to underdeveloped countries, research priorities, and the interpretation of academic studies of the economics and sociology of technological innovation.

89. But it was still fundamentally an era in which the attitude towards science and technology was optimistic and hopeful. If the world was in trouble, it was because it had too little, or the wrong kind, of science or had not learned how to use it effectively. Much of the thrust of science policy as it developed within the OECD area was concerned with bringing the level of total R & D expenditure as a fraction of GNP in individual countries up towards that of the United States (the magic 3 per cent "research ratio"). In this thrust R & D was regarded as a valuable investment in its own right, almost independent of its subject matter (provided it was sufficiently advanced and "sophisticated") and independent of coupling to the operational problems faced by governments.

90. The third phase may be described as the period of disenchantment with science and technology. It began in the early 1960's in the United States; it made a more belated appearance in Europe, generally less acutely and in different forms. However, on neither side of the Atlantic did the recognition of the leeway to be made up prevent the questioning, first, of the major programmes hitherto assigned unquestioned priority, and then of the goals to which the overall orientation of science and technology had been guided. However differently these problems may be perceived, the questioning of the aims of science policy finally merges into the questioning of the processes and ends of science itself.

91. Scientific research became associated in the minds of many with war, and with environmental and social deterioration resulting from the large-scale application of technology. For the first time in many years, the steady and occasionally

spectacular growth of R & D began to falter, and scientists, whether deservedly or not, lost some of their influence and credibility in government and before the public. Interestingly enough, the attack on science and technology came from both the right and left. From the right they were viewed as wasteful pastimes of scientists of doubtful value to industrial development, from the left as instruments of economic and military domination and irrelevant to the pressing social problems of the day. High-technology industry was regarded as regressive in its impact on income distribution, and science itself anti-egalitarian in its organisation and mores. Economic growth ceased to be regarded as an unmixed blessing.

92. Here one can recall the two main recommendations of the Piganiol Report (1) as a measure of the distance travelled since that report was written. The first was that each country should set up a central mechanism for reviewing the total national effort in science and technology, its growth and relevance to, as well as its influence on, a wide spectrum of other national policies. For almost all countries the promise held out by new scientific advances for national prosperity and well-being appeared to be much greater than the available resources in equipment, manpower and finance. The task of science policy was essentially to allocate scarce resources on a more rational and coherent basis.

93. The second main recommendation of the report invited the OECD to call a meeting of Ministers responsible for scientific affairs. In fact, a series of three such meetings have been held since 1963. At the first only some four countries had Ministers specifically designated for science; most of the other participants were Ministers of Education, indicating that, as late as 1963, science was regarded institutionally in most countries as an element of cultural and educational policy. Indeed some countries questioned whether OECD, as an economic organisation, was a proper place to hold a meeting of Science Ministers at all. By the time the Second Ministerial Meeting of Science took place, just over two years later, three quarters of the countries had Ministers designated as "for" or "of" science, while in 1968, at the third Ministerial Meeting, several of the Science Ministers were accompanied by their economic colleagues.

94. Science and the economy has thus been a theme of increasing prominence during the past decade and has been discussed at each of the Ministerial meetings. Nevertheless the early part of these years can be considered as "the naive period" of understanding of science in relation to the economy. The relationship

(1) Science and the Policies of Governments, OECD, Paris, 1963.

between economic growth and R & D investment turned out to be far more complex and far less linear than originally supposed; moreover, the experience of the OECD countries in the 1960's has shown that the management of a country's scientific and technological resources was far more delicate than had been suspected, and that coordination between economic policy and science policy was easier to advocate in principle than to put into practice.

95. One may suspect that the right action was often taken for wrong or insufficient reasons: building up scientific capabilities was no dount right, but basing it on the implicit assumption that research and development expenditures necessarily mark a directly proportional contribution to growth was unwarranted. This is not to say that R & D does not contribute to growth; it most certainly does, but this relationship has to be seen in the framework of a more complex process whereby what accounts for growth is in fact total innovation, i.e., the sums of original and imported innovation and of the funds spent on probing the market for new products, ironing out production bugs, and achieving adequate reliability in the commercial product.

96. The technological gap studies and their discussion at the Third Ministerial Meeting of Science proved to be a turning point in the evolution of science policy, in that they called attention to the problems posed by the nature of technological innovation. These studies revealed that disparities in national R & D effort did not by themselves give rise to major differences in economic and trade performance and that, in the innovation process, the assimilation of new knowledge derived from research and development could not usefully be considered in isolation. Many other factors are involved, including capital availability, fiscal policy, management competence, and attitudes, entrepreneurship, marketing skills, labour relations, general levels of education and even culture and national psychology.

97. Furthermore, nations would prosper by intelligent use of the transfer of technology from other regions. Such secondary or imported innovation demands a high level of education and a sizable domestic research effort; the problem is to create an awareness of world technological trends so that a selection of relevant new developments can be made efficiently. However, the selection of technology does not require as high a level of R & D effort as does the generation of new technology. It was also suggested that original innovation is necessary in a nation if it is to realise its capacity for development in the more advanced science-based industries. We can import technology up to a certain point, but there comes a time, as illustrated by Japan, when a country has to generate its own share.

98. One aspect of this problem of technological innovation potential received much attention without, however, full consensus being reached as to its significance, namely, the economic value of the "spin-off" from military and space research and development. This is very important because such a large percentage of R & D expenditure in many industrialised countries is spent for military purposes. There was no question as to the value of the products derived directly from military and space technologies such as jet aircraft, computers, and integrated circuits, although even in this area there was a question as to how much derived from direct government R & D investment and how much from induced demands for the products. It is a historical fact that these products were developed under a military impulse, but it would be difficult to prove the view that they would not have been developed at all without the sense of urgency produced by military needs and the disregard for economic profitability that goes with it.

99. But there is little doubt that, at least, their development would have been considerably slower if the military incentive had been absent. More controversial was the "spin-off" supposedly manifested by the industrial application of materials, processes, and devices perfected for military and space purposes, in new techniques for managing complex technological developments, in the raising of standards of technology over the whole field of manufacturing industry, and in the levels of education.

100. There was also the question of what could have been achieved in economic benefit if some of the same technical resources had been available to the civilian sector. The correlation on a national basis between military expenditure and economic growth in the past 25 years clearly seems to be negative. Japan is the outstanding example of this trend, having had the smallest military budget in percentage of GNP and the highest growth rate among industrialised nations, while the United States spent a very high percentage of its GNP for the armed forces and achieved only a moderate growth rate. However, whether there are any causal connections in these examples is open to argument. Because of the intangibility of these relationships and the absence of reliable measures of the economic value of research, it has been possible to use the idea of spin-off to justify technological investments having no obvious relationships to social or economic benefits.

101. The fact is, however, that the idea of spin-off provides less and less justification for technological investments, as advanced technologies become more sophisticated relative to civilian needs. Thus the political argument that the benefits of spin-off could be obtained solely from military and space programmes - these representing the challenges necessary to provoke nations to greater technological efforts - becomes less convincing. Furthermore, one should not overlook the possibility of some spin-off from civilian technologies. Though the

argument regarding military-space spin-off may have some historical validity, there is a growing recognition in both political and scientific circles that the problems faced by our societies today constitute new challenges that can be met only by major technological and scientific efforts of different character than in the past. This circumstance makes technological programmes for social ends politically much more feasible than they would have been a decade ago. The very success of the military-space technologies in meeting the ambitious goals set for them causes society to raise its sights with respect to socially oriented technologies. However, the question remains as to whether in fact society will be prepared to pursue these aims with the same political will and commitment of resources.

102. It is important to draw another distinction: the overall growth of resources allocated to science and technology in the OECD countries does not imply that either the R & D efforts or the institutions created to implement them have all followed the same pattern. Quite the reverse, the sizes of the several countries, their relative levels of industrial and scientific development, and their specific problems in formulating science policy have led to appreciable differences in institutions and decisions, and the sensitivity of countries to problems that may also exist in other countries has not aroused identical or simultaneous reactions. For the rest, whatever may have been the aggregate growth in national research efforts, they are far from being comparable either in absolute value or as percentage of GNP. Furthermore there are substantial variations in the distribution of performance of R & D among governments, the universities, and industry. In assessing science policies in the OECD countries, it is important to bear in mind these differences, which are often more important than the points of convergence or similarity. In practice, whereas 10 years ago it was presumed that science policy called for a common pattern, experience seems to show that the paths followed by industrial and post-industrial societies can be quite diverse.

103. For example, in most European countries, the first great problem was to overcome the backlog caused by the war. For some countries, the lead gained by others in the advanced sectors of scie and, above all, technological research, proved all the more difficult to overtake since the possibility of research on all funds fronts was compromised by changes in the cost and dimensions of scientific and technical activities since the end of the Second World War. Military research acted as a stimulus and a multiplier: this role was particularly evident in the countries possessing nuclear arms and prepared to play a big part in space competition. But if, in some countries, the bulk of R & D investment went to the military, nuclear, and space sectors, this was not true of many others, whose priorities were not coloured by strategic considerations, assuredly the most persuasive in ensuring increased research efforts. On the other hand, in every country research activities have enjoyed

increasing government support, based on an intuitive faith that it would produce commensurate social or economic benefits.

104. During the 1960's, science policy in the OECD countries was considered as an independent variable of policy, only loosely related to the total social and political context. Just as economic growth came to be regarded as an end in itself, rather than as a means to attain certain social goals, so science policy became attached to the "research ratio" as a kind of touchstone of scientific success independent of the content of R & D activity or its coupling to other policy objectives. It is true, of course, that basic science requires a high degree of internal autonomy in decision-making in order to make progress most efficiently. In the 1960's there was a tendency to ascribe this same internal autonomy to technology in the expectation that the by-products of technology for national missions would also accrue to the benefit of other social goals.

105. Thus technology policy tended to be viewed in somewhat the same light as policy for fundamental science, with investments in technology treated as good in themselves. This attitude is, perhaps, reflected in the terminological coupling of research with development, even though most development cannot be generalised, diffused and re-used in the same way as can research results. As technology is directed more towards the solution of problems that have large social and administrative components, the autonomous approach to technology is even less appropriate today than it was in the 1960's.

106. In effect, science policy in most countries comes down to research policy. The only fields in which there has been an effort to develop different aspects of national or international policy by the use of science and technology are military, nuclear, and space research; efforts to link the scientific and technical venture to growth policies have been essentially confined to a policy of financing research regardless of the aims it may serve. It is not surprising that a series of difficulties should have arisen from this partial approach.

107. In many countries the agencies responsible for science policy have in fact no responsibility for research connected with defence, and it follows that this important field of scientific and technical activity counts for little in general considerations of science policy. In some countries education policies, especially those that, in higher education, are directed towards the production and training of researchers, are formulated independently of science policies; or again we could cite the case of countries in which research policy is quite unrelated to the efforts to modernise and develop industrial structures.

108. We do not mean to imply by this summary that research has no benefits for society apart from the specific social aims to

which it is directed. But these benefits are indirect, often accidental, and difficult to quantify. While they may constitute a plausible rationale for policy for fundamental research, they become increasingly inappropriate as we move towards the applied and developmental end of the research spectrum. Yet this has tended until quite recently to be the attitude in science policy across the whole spectrum from pure research to development.

109. It must further be added that, in many cases, even essentially research-oriented science policies are themselves partial; it is only a fraction of research that is the subject of major policy decisions, generally excluding the social sciences, or even those of the natural sciences that seem less interesting for reasons of fashion, prestige, or apparent return. Similarly, whole sectors of research, such as health, are often ignored in science-policy decisions, which tend to be related mainly to areas that seem to be allied to the large technological ventures.

110. The predominance of sectors, such as military, nuclear and space research, that respond to goals imposed by considerations of defence or national prestige, leads in some degree to the unbalanced development of research fronts, but much more to the unbalanced exploitation of research results. The way these programmes have been conducted has led to bottlenecks (by creating needs for manpower that is in constant danger of being thrown out of employment by sudden changes in orientation) and the sacrifice of sectors, particularly in technology, that could make better contributions to economic and social development.

111. Moreover, very few countries are concerned to foresee future research and educational needs in the light of the trends of their university and industrial development, and to define the research sectors that, in that light, merit special support. Granted that too much orientation of science (as opposed to technology) is self-defeating, this does not mean that it is wholly futile to exercise qualitative professional judgements concerning areas of promise for future social and industrial needs. Yet even this minimum of discrimination was exercised only sporadically and not in any systematic way, comparing a full range of alternatives. In the 1960's, methods and techniques were developed with a view to refining decision-making and, in particular, to giving greater effectiveness to research and development activities in the context of well-defined policy objectives. The use of these tools constituted a major innovation and the difficulties encountered in applying them does not mean that that their use and further perfection should be dropped. However, more discriminating and quantitative judgements should have been possible with respect to technology and applied research (1).

(1) See Analytical Methods in Government Science Policy: An Evaluation, OECD, DAS/SPR/70.53, October, 1970 (mimeographed)

112. As with most new intellectual tools, technological forecasting and systems analysis were oversold by their proponents, and awareness of their limitations under conditions of technical uncertainty, conflicting goals, and implicit non-scientific value judgements grew only gradually. We believe that these methods will find their true place in the coming decade - more modest, perhaps, than the original claims, but nevertheless of substantial significance, especially when many alternatives and possibilities are available.

113. Policy for science and technology is only one element of overall public policy; thus, it must be recognised that the search for the "optimum", whether in relation to the aggregate amount allocated to R & D activities or to methods of management and execution, is more an art than a science, and it is unrealistic to expect otherwise. That is, however, no reason for not trying to link R & D effort more closely with a planning effort, or, in other words, to introduce greater consistency between decisions affecting research activities and other policy decisions.

114. If science policy consists in getting the best out of the resources of science and in promoting technical innovation to attain national goals, it is essential that its links with other areas of government action directed towards the same ends be clearly understood. Study of innovation process and a growing appreciation of the complex of technological, socio-economic and managerial factors have indeed revealed the limitations of the policies previously followed: first, the different elements of science policies were usually treated independently of each other; second, science policies themselves were often treated in relative isolation from other policy decisions.

The International Effort: Competition or Cooperation?

115. If science, by its nature, transcends national frontiers, science policies, for their part, are formulated and applied within the limits of national sovereignties. Since the Second World War, governments have recognised scientific and technical cooperation as a way of achieving some of their aims more rapidly and economically, and have therefore taken common action relating to all forms of research, from pure science to technological development, making use of various mechanisms. Cooperation has involved the establishment particularly in Europe, of international programmes and institutions for cooperative research, especially on topics too expensive to be undertaken by individual countries. This could be regarded as a means of extending national resources through international cost-sharing, but it has often been initiated by successful pressure groups of specialists in particular disciplines or for specific political reasons rather than for reasons of overall policy, involving more systematic review of alternatives.

116. Today, the OECD countries are calling these joint undertakings into question. The programmes of some organisations, and even the organisations themselves, are being challenged (e.g., in the nuclear energy and space sectors in Europe); some countries have even withdrawn from the cooperative programmes at issue. An evident uneasiness is spreading among government, scientific, industrial, and academic circles. The doubts aroused in some quarters by multilateral cooperation encourage the belief that bilateralism is the only effeciive means of cooperation, but this is only a postulate, and is at best questionable.

117. International action adds its own specific obstacles and restraints to the difficulties inherent in all research undertakings. What would pass at the national level for an error of direction, management or foresight will sometimes be seen at the international level as a consequence of divergent views among the partners as to aims and programmes, or as to the equitable sharing of risks and benefits. In this sense, the setbacks encountered by joint scientific and technical ventures such as certain programmes of the European Atomic Energy Community (EURATOM), the European Space Vehicle Launcher Development Organisation (ELDO), or the European Space Research Organisation (ESRO) are mainly the backlash of the divergent options followed by national science policies; these policies, for reasons of inability or unwillingness, have not had the effect of freeing international commitments from the drag of national rivalries. Political difficulties, moreover, may sometimes serve as a screen or pretext to cover up technical errors.

118. It is essential to distinguish joint enterprises whose objectives are purely scientific from those aimed at application. Once the enterprise is launched, the weight of political factors is obviously lighter in the first case than in the second; there is less dispute about the objective pursued and the results hoped for; whatever the differences in investment, the gain is always a common good, because knowledge is not diminished by being shared. Moreover, precisely because it is the extension of knowledge alone that is involved, the result can be evaluated only by the yardstick of scientific achievement, which is universal and does not touch national values or interests. The scientists, who alone can make this evaluation, belong to a single community with a common standard of values so far as their science is concerned. In the case of scientific research it must be assured, of course, that an international laboratory does not become a high-quality scientific monastery, cut off from those it serves. One of the reasons for the undoubted success of the European Organisation for Nuclear Research (CERN) is that its equipment is used by all the universities of Europe and its programmes are geared to their needs; researchers using CERN also teach in their own universities.

119. Conversely, as soon as application comes into the picture, the weight of political factors grows to the extent that scientists are no longer solely responsible for deciding on the orientation of the project and the value of the results. The effect of the weight of political factors in relation to the technical factors is uneven according to the type of joint enterprise, but it is always present. From the point of view of the management and execution of the research programmes, political considerations become, in effect, multipliers of difficulties. The budget of an inter-governmental establishment is subject to the hazards of the economic situation in different Member countries; a crisis in one may have repercussions on a whole programme in relation to which the others show no financial reticence.

120. It is therefore difficult to analyse the comparative effects of political and technical factors and all the more so because there are no studies on the management of international scientific undertakings. Case studies of this kind in depth would meet a real need. Here we must be satisfied with indicating some obvious difficulties - just because they are so obvious or because the crises undergone by various cooperative projects have brought them to light. All these difficulties combine to demonstrate, first, that cooperative action should never be conceived as a substitute for national programmes but as a complement to those programmes integrated in a coherent policy, and, second, that there is no technical, managerial or social substitute for the expression of a common political will.

121. Governments committed to international scientific, technological, and technical cooperation have rarely started by defining the fields in which the scientific and economic interests of their countries and their respective partners lay. There has rather been a tendency to regard cooperation as an end in itself, without spelling out the indirect scientific, technological, political or economic benefits it afforded to each of the participants collectively and individually. But if it is essential, at the national level, to refine these decisions by studies linking the scientific data with the political and economic data, this need is even more urgent at the international level. Governments have, in practice, often committed themselves to cooperative action without having considered the medium term implications. The rules and principles that have evolved in recent years for managing international organisations should be examined to see whether they are appropriate to the common purpose of those organisations.

122. It is idle (and, indeed, needlessly expensive) to launch a cooperative research programme if it is planned or used as an instrument of competition at the expense of any of the partners. The definition of activities should be a genuine common enterprise; otherwise cooperation is self-contradictory. Once the venture is launched, it is even more costly to take part in it

with such restrictions and reservations that the slightest crisis experienced by one of the partner countries reopens the whole issue of the joint undertaking.

123. Thus, it is not surprising that governments tend to measure the results of international cooperation in research solely by the financial input each has made rather than by the output measured against a benchmark agreed upon in advance. Every research activity is exposed to certain risks and success is never guaranteed; the custom of a "fair return", which may be explained by the political context (that is to say, the absence of economic and political integration) is certainly not the most favourable basis for the consistent formulation of a programme, the rational distribution of tasks and financial commitments, and the final achievement of the common ends.

124. The present spirit of disenchantment with multilateral cooperation should not be allowed to disguise the reasons that will continue to induce, and sometimes compel, countries to engage in joint action. In certain sectors of fundamental research the size of the equipment and research units required is so great that many countries, even the wealthiest, no longer feel able to meet the cost on their own, and this is even truer of applied research and technological development. Even what has been traditionally thought of as "small science" can often benefit from the sharing of access to highly specialized instruments and from complementarity in the planning of experiments. Much of this may go on in the normal course of collaboration among scientific colleagues without any formatities, but as the specialization of instrumentation and skills grows in each field, the incentive for more formal joint planning or the bringing together of scarce specialists in one laboratory increases.

125. As we look ahead to the near future, it becomes evident that advances in technology and in the increased application of technology are going to make it necessary for a substantial expansion of the functions to be carried out in an international framework. In particular, there will have to be a degree of internationally based regulation, control, allocation, and operation that goes well beyond that which exists today. Another way to say this is that there will be greatly increased constraints on the independence of nations in many technologically related areas. Thus the locus of decision-making will increasingly move from national to international forums.

126. This development can be seen in many different areas: environmental alternation (including pollution), ocean resources, space applications, natural resources depletion, food, population and others. In each of these areas of concern governments will be "forced" to seek the establishment of international regulations and standards in order to avoid serious environmental effects, or to assure equity in the allocation of resources as in trade,

or to achieve the benefits of new technology, or to settle international disputes caused by the use of technology, and so forth (1). It should be noted that new technologies usually cost more to develop than the ones they replace. For example, nuclear power stations cost more to develop than fossil-fuel power stations. There comes a time when international action is required to develop new and expensive technologies.

127. From this perspective, if we now evaluate the existing international machinery to carry out these function, we find that much needs to be done. In fact, all the functions are performed today, some substantially but most in embryonic form. It is a mistake to argue, as some do, that nothing is done successfully by international machinery and that revolutionary departures are absolutely necessary in international organisations. However, when compared with what will be needed in the 1970's, in terms of the scope of coverage, of the complexity and number of the technical issues and the interactions with other issues, and the increased political and economic importance of the subjects, the existing situation must evolve and change substantially. It will be necessary to look to international machinery to deal with the functional technologically related capabilities that these changes will demand. Here the potential role of the OECD as a source of a analysis is obvious.

Science Policies and Underdevelopment

128. We have already stated that science policies have been considered too much apart from the social and political context in which they operate and which, in fact, they strongly influence. Nowhere is this more evident than when we consider science and technology in relation to the problems of the developing countries. The scientific and technological progress experienced by the advanced countries, while, in principle, opening up important production possibilities for the developing countries and demonstrating the potentialities created by the ever-increasing control achieved by man over nature, has also led to some imbalances in their economics.

129. The science policies pursued by the advanced countries are not in themselves, of course, directly responsible for this situation. It results principally from two causes: first, underdevelopment as such, which forms a basic obstacle to the application of science and technology by the developing countries,

(1) See E.B. Skolnikoff, The International Imperatives of Technology - The implications of technology for future development of International Organisations, Carnegie Endowment for International Peace, Geneva, March 1970.

and, second, the present organisation of international economic relations on the basis of a market whose rules are largely set by the advanced countries, often consciously or unconsciously in their own interest. Moreover, the fact that modern techniques have been applied to a small industrial sector in the poor countries without being adapted to their total situations, while they have hardly touched the remainder of the economy, have not improved the situation. Also, scientific institutions in these countries have often been established in too direct imitation of Western models.

130. In order to point out the limitations of science policies in relation to this problem, it is important to bear the following two facts in mind:

(1) Only a tiny fraction of the world's research and development effort takes place in developing countries. Furthermore, very little of the R & D effort in the developed countries has direct bearing on the needs of the developing countries. Thus the relative positions of the developing countries in science and technology are even weaker than they are with regard to production and capital formation;

(2) For a long time to come, therefore, the less developed countries will have to increase their productivity mainly through the application of imported technology, adapted where necessary to their own natural and socio-economic conditions.

131. It is not our purpose to discuss here what must, in any event, be done by the developing countries themselves to overcome their handicaps, adapting their economic structures, and creating or developing the scientific and technical resources that will enable them to make the best use of the knowledge and innovations available from the world. What we wish to emphasize is that world stability requires that responsibility be assumed by the advanced countries in this respect, and the fact that their science policies have a part to play that they did not play in the 1960's.

132. This responsibility is all the more evident when we take into account the influence exerted by the science policies of the advanced countries over the qualified manpower resources of the less developed countries. Of course, the market for scientists and high level-technicians is international. But, on the one hand, most of the less developed countries do not have institutions and economic structures that can absorb the output of their higher education systems; on the other hand, since the educational systems of these countries are modeled on western systems so that graduates are oriented towards western employment, it is not surprising that R & D programmes of certain advanced

countries attract high-level technicians from the less developed areas. The qualitative drain may be still greater since these often are highly talented and enterprising people.

133. Nearly all scientific activity is conducted by the industrialised countries, which possess more than 90 per cent of the world's scientific workers. Furthermore, in spite of its paucity, much of the research conducted in the Third World is towards the scientific interests of the industrialised countries; the rest is often scientifically and economically sterile, because it is done in very bad conditions and with no serious effort of application. The situation in the non-industrialised countries has been called a "research desert", but three quarters of the world's population live in that desert. If science is to contribute to economic and social development, it is hard to find any more inspiring challenge to science policies than that of underdevelopment.

134. The so-called brain drain draws off scientists and engineers and other highly educated people into the labour market of the developed countries, thus apparently exacerbating the situation described above. However, the problem is deeper than this since there are already many unemployed scientists and engineers in the less developed countries and their education and motivation are inappropriate to the technical needs of their countries. Repatriation of these individuals without other actions would only further exacerbate a bad situation. It is necessary to get at the basic causes of the underemployment of technically qualified people in the less developed countries, a problem that requires positive cooperative actions between those countries and the more advanced ones.

135. Thus it seems clear that the foreign-aid policy of the developed countries must be closely connected with their science policies. Over recent years, the few successes in scientific and to the developing countries - the creation of new research institutes, the financing of special scientific projects by the UN Development Programme and by UNESCO, as well as by American foundations, certain Institutes in the United Kingdom, and the French Office for Scientific and Technical Research Overseas (Office de la Recherche Scientifique et Technique Outre-Mer) - ORSTOM - would not have been possible without the active cooperation of the international scientific community, and more might have been achieved had top national science policy makers played a more dynamic role in these operations.

136. It seems necessary to think in terms of entirely distinct forms of expenditure:

(1) That which is intended to help the developing countries increase their own research activities and, at the same time, develop the institutions

that will allow these activities to be oriented towards the solution of the most urgent economic and social problems and the mechanisms and structures for reception that will allow foreign technologies to be imported and adapted under the best conditions;

(2) That which is intended to bring part of the research potential of the advanced countries to bear on programmes and projects designed to solve some of the most crucial technical problems that the developing countries are not themselves in a position to tackle for the time being.

137. The important point is to distinguish expenditure for the development of research and allied activities in the developing countries themselves, and expenditure relating to the problems of these countries incurred in the research effort of the advanced countries. Each of these two forms of expenditure has its own importance; if they are to be fully effective, it is obvious that they should be conducted in parallel and treated as fully complementary.

138. But this is precisely what has not been done, or even attempted, in the 1960's. So long as this responsibility is not recognised as one of the essential functions of science policies of the advanced countries by linking aid policies with policies for scientific and technical action, both nationally and internationally, we are convinced that there is little chance of any great progress.

The Challenge of Setting New Priorities

139. In the last 30 years science policy priorities and choices have been determined largely by external challenges such as defence, national prestige, or competition in world markets rather than by other social needs such as the improvement of public services, the elimination of poverty, or the improvement of public health. These older priorities may be questioned on moral, political, social or scientific grounds; however, in terms of technological advances, it cannot be denied that many specific goals have been met. The success was due not only to the management methods thus developed but also to the fact that the targets were clear and straightfowward, and the necessary fundamental knowledge was for the most part either in existence, or there was sufficient theoretical understanding to know where to look for it. If there is a lesson to be learned from past experience it is that clear goals, plus the requisite state of development of the underlying science, are perhaps the two main factors of technological success, and that, given these, a well-defined technological objective can usually be met, given enough money and an adequate supply of high-quality manpower.

140. Within a given field of activity, it is possible and often easy to set priorities among targets and to acquire the means necessary to achieve them. The cost of the various methods envisaged and the estimate of the possible return on such investments are circumscribed within the framework of the exclusive interests at stake. These methods may be applied to the choices that have to be made by a specialised governmental agency; they make it perfectly feasible to compare the relative costs and benefits of different programmes designed to achieve the same ends. In such a context "the choices are the same choices that minimise the cost of achieving that objective"! - in other words, "the strategy which is most efficient is the most economical"(1).

141. The conditions for the success achieved in many space and defence projects are not yet evident in the social sphere. The goals are complex, unclear, and the subject of conflicting interests and a wide diversity of values and preferences among the people affected. The underlying basic knowledge is spotty, fragmented, and often not firmly established in a scientific consensus. Not only is it more difficult to achieve the ends proposed, but also, if not mainly, it is more difficult to determine what the ends themselves should be. In a democratic society, the problem of goal-setting gives rise to an arbitration between conflicts of interests in a context of imperfect information, ambiguity, negotiation, and divergent pressures. Competing value judgements multiply between budget considerations of economy and political considerations of needs and effectiveness.

142. Furthermore, even if there is a consensus on the value to be attached to certain social ends, this is not sufficient to determine the programmes that can meet them. Many of our social goals are stated in too generalized terms to be readily translatable into concrete, applied research tasks, at least in the present state of basic understanding. Moreover, we are dealing not with a single, simple goal but with a complex of mutually dependent and interacting goals. If we commit ourselves exclusively to achieving one goal, we may find that we have created entirely new problems or failed on other goals of equal importance. Thus the situation is something like a soft pillow, which, when we push it in one place, bulges out in another. These difficulties are particularly great in the case of R & D activities because the state of knowledge is not even sufficient to allow us to specify what we don't know and hence to design the research to find it out,,let alone develop the necessary remedies. We are

(1) Charles J. Hitch and Roland N. McKean: The Economics of Defence in the Nuclear Age, Harvard University Press, Cambridge, 1960, (Atheneum Edition, 1963, p. 2-3)

forced to proceed much more empirically, since some of the problems are too urgent to wait for understanding, even though we know we could do much better if we could afford to wait for the slow, painful, and error-prone process of gaining the requisite understanding. In social and environmental systems we have nothing like Newton's law of gravitation to predict the course of a social or environmental system in response to our remedial measures.

143. To the extent that problems and goals have a non-technical component, the correct formulation of the problem so that it can even be addressed by the methods of science and technology becomes itself a demanding intellectual task. Systems analysis has been one approach to this intellectual task, but we do not possess a tested technique of systems analysis that is applicable in the presence of conflicting goals and values among different segments of the affected populations. Whether such an extended form of systems analysis can ever be developed is a matter for argument and speculation.

144. We lack an adequate science for the management and measurement of complex interacting systems and a rationale for breaking them down into sufficiently isolable sub-systems such that analysis of the sub-systems yields results that are relevant for the policies to be used in dealing with the system as a whole. In the discussion of ecological or social systems, it is not enough simply to say that everything depends on everything else, and so we must look at the whole system. This too easily becomes a counsel of despair and, in the area of policy, a pretext for inaction. The essential method of science is to break down global problems into discrete and soluble problems, and we must be prepared to do this in tentative ways, while realising that any particular breakdown is only a first approximation, and we may have to start over again after proceeding some considerable distance.

145. The setting of priorities in science and technology in the context of many of the social goals that are coming to the nature of the stage constitutes a formidable challenge to science policy. In many ways we will be forced to proceed along two parallel paths, and the setting of priorities between these paths will involve a delicate balancing of long-term and short-term considerations. One will be a short-term "applied" approach based on current data and understanding, imperfect and incomplete a as they are. This will involve high risk and may result in the pursuit of many wild geese. It will beexpensive in operational and investment terms and may produce some spectacular failures with unpleasant political sequels. Some of the problems are too urgent to avoid this risk.

146. At the same time, we must pursue long-term programmes aimed at understanding rather than at immediate solutions.

We cannot predict in advance when such a programme will yield insights pointing the way towards new applied research directed at concrete solutions, or which may indicate reformulation or reorganization of our applied goals. We shall just have to wait, recognizing that this is the inherent nature of the scientific process. There will be many temptations to take off on the basis of incomplete or misleading data and partial insights, which will sometimes be resisted and sometimes not. The assessment of when to take such risks in applied research or operations is the essense of science policy.

147. The longer term programme implies a policy for the research end of the R & D spectrum based primarily on internal criteria of choice. While the strategic choice of broad fields for selective emphasis must be guided by social goals and, in part, by judgements as to the ripeness of the general field for rapid progress, the choice of scientific problems and projects within a broad area is tactical and must be governed almost wholly by internal scientific criteria, i.e., their contribution to conceptual understanding in the broad area. Any setting of merely tactical priorities on the basis of social goals is likely to be self-defeating and wasteful. With respect to the developmental end of the spectrum, the policy must be quite different, with selectivity designed to take advantage of existing knowledge and an overall perspective on the goals to be achieved.

PART IV

SCIENCE POLICY IN THE SEVENTIES

148. If our societies are to continue to grow and simultaneously to cope with the byproducts of economic growth, science policy must continue to concern itself with the promotion of technological innovation.

149. The diversification and intensification of collective needs and aspirations are among the most lasting and most far-reaching consequences of economic growth. The satisfaction of such collective needs will occupy an increasing fraction of society's attention in the 1970's and beyond, and will thus constitute a growing dimension of science policy.

The Formulation of Problems

150. For Member countries, the period that is now opening will call for a special effort to adapt to the changing nature of problems that have emerged unexpectedly, either because they have too long been overlooked by economic policy, or because the solution of some of them has called forth others: one such problem, for example, is the overgrowth of metropolitan areas and the economic and social stagnation of smaller communities. Another is the rapid decline of short-distance public transportation as a result of widespread ownership of motor-cars. Many disbenefits of technology take the form of subtle threats to health that have no readily visible manifestations but could assume near-crisis proportions before public awareness is aroused. Thus, a world in which individual hopes had an elemental and concrete character has given place to a world in which satisfactions generate new needs and in which, as a result, hitherto undetected problems may rather suddenly lead to acute social dissatisfactions.

151. The systematic identification and formulation of new problems are the more necessary because the distinguishing characteristic of much of the present social demands is that they are defined more by the dissatisfactions they engender than by a precise formulation of the satisfactions looked for: existence of dissatisfaction, in other words, does not automatically imply a recognition of preferable alternatives. The very complexity of society and limitations of knowledge make it difficult or impossible to envisage realistic alternatives. This is one of the frustrations of modern society; today's "hungers" are not easily defined. Thus, environmental pollution, the chaos of city life, and the inadequacies of the universities arouse discontent that is not expressed in precise alternative concepts of the types of environment, city, or university desired.

152. Although in many cases these discontents may be based on mis-perceptions of the objective situation, we must recognise that the perception is itself part of reality. Thus the discontent cannot be alleviated by physical measures alone, it requires an understanding of the total situation. It does little good, even if it is true, to tell the city dweller that the air in London and Manchester is cleaner than it was 100 years ago.

153. Thus it is very important to use knowledge to define an expanded range of alternative opportunities and make them as specific as possible. The search for objectives implies a new approach that would systematically attempt to relate problems emerging from new social demands to actual and predictable techno-economic possibilities.

154. Since problems were for so long deemed to be immutable, functions already assumed became more important than aims. Thus the attainment of major national goals, such as the elimination of illiteracy or the improvement of agricultural yields, called for the development of the relevant government functions, such as education and agricultural policy. In the sequel, within each of these functions, new goals were inferred from extrapolations of goals already achieved; the functions defined the problems to be met, and re-assessment of the problems at hand did not lead to the redefinition of the function. For example, universal literacy ultimately led through this process to the universalisation of higher education in much the same way in which education had been developed for a small elite.

155. The rigidity, fragmentation, and institutional competitiveness of bureaucratic practices are obviously both causes and consequences of this state of affairs. Bureaucratic development is partly a result of the vagueness of aims pursued. The determination of new aims is often not sufficient, however, to overcome these weaknesses, which also stem from the inclination of bureaucracies to resist innovation. For these reasons, contemporary societies are called upon to challenge certain forms of organisation that can no longer render the services they require, because in these societies, change and uncertainty have become the constant companions of prosperity.

156. Thus, it has become a commonplace that many new problems, over the last quarter of a century, have been recognised too late by the government machine, which has often been moved to action only by the advent of a crisis. We may cite in this connection the role of military and space competition for the development of research policy, of sharp public reaction for policies to protect the environment, and of student unrest for the reformulation of education policies.

157. Any attempt to assess dissatisfactions, define opportunities, and formulate new goals inevitably runs counter to established policies that have been instrumental in the emergence of new problems. It will therefore always be difficult to look to operational agencies and policies for an objective effort to redefine aims that may involve agonising reappraisals, challenge existing interests, or simply call for a sense of perspective incompatible with the responsibilities of day-to-day action. For this reason the identification of emerging problems is a function that tends to be overlooked by traditional public administration and therefore cannot be wholly integrated with it. It is a matter for each country, and perhaps for each region, to work out its own institutional solutions in harmony with its own particular traditions and patterns.

158. An essential step will be to create, either at Ministerial level or on the periphery of government, or even outside the executive altogether, a new type of institution, a sort of watchdog of political, social, and economic life, which will be responsible for detecting the threats inherent in progress and for proposing means of harmonising the course of progress with the aspirations of the community. A preliminary step in this direction, for instance, has been the recent creation in the United Kingdom of the Cabinet Policy Review Group.

159. The international aspects of a project of this kind must also be stressed. Most of the problems at issue affect the whole planet, and no man is immune from the social and economic impacts of technological progress. The identification of new problems is therefore also an international task, in the service of which science policy must be enrolled.

160. The broad lines proposed here are, indeed, realistic only so far as they are backed by a new approach to research and development, no longer aimed exclusively at improving existing technologies or producing new ones, but also at perfecting conceptual instruments for the better understanding of man and his society and at delineating the requirements of harmony in social and economic development. This will call upon a synthesis of all the resources of contemporary science, but especially for the increased development and integration of the full range of the social sciences with science policy, and also for the much deeper understanding of the natural environment and the biosphere as a single interacting system.

161. The social sciences have been late in gaining academic respectability, especially in Europe, and have only recently begun to attract superior talent in adequate numbers. On the technical side, the social sciences have made considerable strides, especially through statistics, the assimilation of computer techniques, systems concepts, and other quantitative tools. These have much to offer for advances in the social sciences in the

future. Like all new and powerful tools, these may bemuse their users, causing them to mistake technical virtuosity for profundity of thought. Nevertheless, the potential of these new tools is enormous, both on the theoretical side and ultimately for policy, and initial misapplication or misguided enthusiasm in a few instances should not be allowed to lead to disenchantment and neglect. Much effort will be required to learn how to use these new tools effectively, but the effort will be well worthwhile.

162. We nevertheless desire to reaffirm our strong reservations against expecting too much from the use of scientific and technological knowledge alone. While such knowledge is indispensable in intercomparing and interrelating various needs and aspirations, the final ordering of priorities must depend on man's hopes, fears, and regrets. Science can provide the objects of these attitudes and aspirations and in helping to assure their internal consistency, but it cannot substitute for the aspirations themselves. The identification of new problems, a compulsory function of modern societies trying to recover their equilibrium, is possible only so far as dissatisfactions are perceived, measured, and analysed. The free expression of dissatisfaction is, however, a necessary condition for the smooth running of the system; no mechanism for the identification of needs and the determination of objectives can, therefore, function without the participation of those who are personally concerned. Optimum conditions for change are arrived at when individuals can express their choices freely within the normal processes of the socio-economic system.

163. On the other hand, participation by itself is also not sufficient, if the participants are unwilling to accept compromises of their own satisfactions and aspirations, and to modify their expectations in the light of technical feasibility and objective evidence. The important roles of science and science policy are in clarifying the interactions between goals and delineating more objectively the consequences of various alternative policies and decisions. Successful operation of participatory systems of decision thus requires a high degree of rationality on all sides and a degree of openmindedness.

The Rationalisation of Choices

164. In the face of rising public concern over some effects of technological progress, it is understandable that some people should despair and lose confidence and should turn away from science and technology and even from all exercise of rationality, which they regard as inexorably generating misfortune. Because science is viewed as a rational process, others go to the opposite extreme of expecting a level of rationality in the formulation of science policy that overlooks its dependence on value judgments and its sensitivity to political conflicts. Furthermore, the process of technical innovation is far from being a fully logical one even though its results can be rationalised after the fact.

Innovation is not, and cannot be, an entirely planned process, because it includes the revelation of the not yet known or understood.

165. The development of science policy has nevertheless given rise to much speculation as to the possibility of transposing the quality of the scientific method into governmental action. In particular, the successes of some big technological programmes, have led to suggestions for mobilising other disciplines for better understanding of socio-economic mechanisms and thereby increasing their predictability. However, as has already been pointed out, the goals of the existing big technological programmes were much simpler to define than those likely to be pursued in the future.

166. Finally, research-mindedness itself has struck deeper and deeper roots in contemporary societies, which had reached the point of greater self-questioning. In particular, the growing abundance of information on social and economic phenomena has made it possible in many cases to specify with greater precision the effects of past or future decisions. Because research threw light on certain mechanisms, the political process had to conform to a more rigorous rationality. A new tendency seemed to be launched in this respect. The issue at stake is particularly serious, since it amounts to increasing the role and influence of "social" technology in the process of assessing and ranking the aims set for national and international effort, as in the case, for example, of the growing use of opinion research as a technique for measuring political trends, consumer preferences, or general social perception.

167. From what has already been said, we see that economic growth multiplies perceived needs more rapidly than it generates the additional wealth to fulfill them. Furthermore, technological change constantly reveals the incompatibility or conflict of simultaneously held goals such as the abundance of private goods versus the quality of the urban and natural environment. Thus, as the limitation of available resources becomes more apparent, greater coherence between the different goals of the socio-economic system becomes a prime necessity. Choices have to be made, in the light of the urgency of the needs to be satisfied, of their compatibility, and of the volume of resources required. This process of setting priorities implies the systematic confrontation of goals, the costs and benefits of which should be constantly compared with each other.

168. This ideal scheme, however, is hardly to be found in the daily practice of government action, the rationalisation of which, to speak of technical obstacles only, is hampered by the co-existence of old objectives and new objectives, by the imprecision of budgeting and the inadequacy of the instruments for measuring benefits.

169. The co-existence of old functions and new problems almost inevitably favours the former over the latter, which have to develop in a context in which the bulk of resources is already earmarked under budget mechanisms that respect the past more than they protect the future.

170. Any analysis of the costs and benefits of various policies proposed for government action is necessarily imprecise. The relative weight given to the individual components of cost and benefit varies according to the point of view. A given objective, sufficiently circumscribed, lends itself to comparatively accurate short-term analysis: for example, agricultural policy can be evaluated in relation to the prosperity of farmers. But it is difficult to compare different benefits, especially when they accrue to different social groups.

171. Science policy should aim to improve the technical conditions for decision-making, especially in relation to the comparison of heterogenous aims. For this purpose its task is to construct, for each potential aim, a detailed pattern of its social and economic costs and benefits. This obviously implies a considerable effort to intensify and systematise knowledge about the phenomena in question, and will prove particularly difficult when it becomes necessary to specify induced secondary costs and benefits, knowledge of which is still very imperfect.

172. The optimum use of the results thus obtained will be possible only if new management methods make it possible to equip national administrations with sufficiently flexible structures to ensure that the old functions do not form a too effective bar to the new ones. Furthermore, the refinement and rationalisation of the choices made among different aims corresponding to distinct needs implies a relatively high degree of centralisation. This requirement, while favourable to decision-making, may turn out to stifle the innovation process and may also conflict with the increasing need and demand for the wide participation in decision-making noted earlier.

Organising for the Implementation of Policies

173. Science policy is but one element in the implementation of an overall policy for the satisfaction of collective needs, but one that should be used in such a way as to realize all its possibilities. It should, therefore, itself propose the structures that seem most appropriate for its own effectiveness.

174. Science policy is also, as we have already stated, an important instrument for the clarification of goals. By the same token, it is concerned with the definition of methods and, particularly, with perfecting appropriate political and administrative structures to facilitate the implementation of decisions.

175. Fundamental differences in methods of execution are, however, already making their appearance. The last three decades were characterized by the mobilization of thousands of scientists and engineers in the service of vast programmes with concrete predetermined technological objectives that were often selected without systematic comparison with possible alternatives and no consideration of opportunity costs. The aims of science policy in the future will be more diversified but also more coherent, and will be designed to produce innovations comprising important non-technological components.

176. Research policy during the next few years will therefore include an increasing variety of circumscribed and even highly specific programmes. It may be thought that a situation of this kind requires flexible agencies endowed with wide autonomy and capable of reacting rapidly to events, without deviating from the missions assigned to them. A careful selection and integration of a wide range of changing and sometimes conflicting options, however, seems to call for a central decision-making mechanism.

177. It is not surprising, therefore, that an issue of continuing debate and concern in national science policies has been the determination of a proper balance between centralised resource allocation and decision-making for science and technology as a whole, and a pluralistic or sectoral policy carried out within the various sectors of social or economic policy served by research and development. In practice there is no national system of science policy that follows either the pluralistic or the centralised model in its ideal form. Any viable system of science policy must involve some blend of the two idealized approaches. Each tends, with time, to develop its own rigidities and limitations, and some shift in the mix from time to time may actually be desirable in order to open new lines of communication and linkage. Such periodic "shake-ups" probably help the overall system to adapt to new social goals and thus to be more responsive to the changing needs of society.

178. In the pure form of the pluralistic approach, resources are assigned to each policy sector as a whole - e.g., defence, health, agriculture, transportation, housing, social welfare - and the appropriate level of R & D for each sector is then determined in competition with capital investments and service expenditures in the same field. The overall science policy is then the sum of the policies arrived at, in a first approximation, independently for the individual sectors.

179. The advantage of this scheme is that the research and development activity tends to be well coupled to the operational needs of various social goals and more responsive to these needs. At the same time new technological opportunities or new scientific knowledge of value to the achievement of sectoral goals are more likely to be brought quickly to the attention of the operating

arms of the agencies responsible for that sector. The disadvantage of the scheme is that it places the long-term and short-term needs of the sector in direct competition with each other. As a result, the longer-term needs may suffer, especially in periods in which the total resources available to the sector are restricted or declining. A second disadvantage is that the definition of the scientific and technological goals in the sector tends to become static, and new opportunities or the redefinition of overall goals based on new knowledge or understanding arising elsewhere in the total scientific-technological system tend to be overlooked. Furthermore, in times when goals are uncertain or changing rapidly as at present, the effort to match sector science policies to short-term changes in sectoral policies comes into conflict with the inherently long-term nature of scientific effort, which becomes very inefficient in the presence of too rapid shifts in demand in relation to manpower or facilities requirements. Thus the pluralistic model tends to work most effectively when sectoral goals are fairly constant and the total resources available to the sector are growing.

180. Until very recently the conditions for the success of the pluralistic system were well fulfilled in the American situation, and American science policy has actually approximated to the pluralistic model with success. Recently America has been undergoing a searching re-assessment of its goals, simultaneously with tight restrictions on budgetary resources. New socially oriented goals are coming to the fore while the long-term emphasis on space, defence, and atomic energy has begun to recede visibly. This has produced severe strains and dislocations in the American scientific establishment, which have led the American scientific and technological community to look with greater favour on more centralised models of science policy.

181. In the pure form of the centralised model, all resources for publicly supported research and development would be given to a single agency, which would then determine the allocation of these resources for scientific and technological activity serving the purposes of the various sectors as well as for the maintenance of the health and vitality of the scientific establishment as a whole. Although some OECD countries espouse the centralised model in principle, none follow it very completely in practice. The advantage of a centralised system is that it facilitates a more effective use of limited technical resources in manpower, facilities and money, and that it encourages the development of an overall coherent policy for technical activity that avoids the sudden shifts so disruptive of scientific accomplishment.

182. To the extent that scientific and technological knowledge is itself an ingredient in the identification and definition of social goals, a centralised system of resource allocation and decision can increase the flexibility and adaptability of the system, especially when measured against a time perspective longer

than that inherent in the nature of the political process that sets social goals. The disadvantage of the centralized scheme is that it is likely to be less responsive to the operational needs of the various sectors, and the results of research can more easily be ignored or overlooked in sectoral planning. Thus the centralized system for science may result in an element of rigidity and excessive conservatism in the operational aims of the various sectors. From the standpoint of the use of technical resources, the centralized system is well adapted to a situation of limited resources and uncertain or rapidly shifting social goals

183. Many national systems that recently approximated to the centralized model are now moving towards a more pluralistic or sectoral approach. Thus there appears to be convergence of all systems of national science policy towards arrangements that embody elements of both idealized models.

184. The mixed scheme just described fairly closely resembles that arrived at in most large science-based firms. Such firms often have research arms attached to each of their operations or product divisions, in addition to a corporate laboratory responsible for long-rage research aimed at developing new products and operations and providing a general technical background for all the firm's activities and decisions. Such firms also usually have a vice president for research who has a staff and co-ordinatin responsibility for the divisional laboratories, but a line responsibility for the corporate laboratory. We believe that the considerations that have led to this choice in most firms apply equally in the case of national governments, although we also recognize that a somewhat different mix of centralized and pluralistic elements may be appropriate for individual countries, especially in the light of their total technical resources. In particular, large countries may have more features of the pluralistic model than do small countries.

185. We have felt it necessary to discuss this issue at some length because we have found a disposition in many countries to regard the centralized and pluralistic models as mutually exclusive alternatives, and to be debating a choice between them in their own structures. Not only do we consider an either-or choice undesirable; we also feel that some degree of shift, with time, towards each of the two models may have a positive value in keeping the overall scientific system both healthy in its own right and more adaptable.

186. Thus, to summarize more specifically, a certain proportion of the total R & D funds should be allocated centrally by a scientific agency in order to assure adequate responsiveness to changing goals, long time horizons, and the development of an adequate knowledge base for the formulation of new goals. Another part of the R & D funds should be allocated by those responsible for individual sectors out of the total operating funds available

to them in order to assure adequate research on shorter-term operational problems and adequate coupling between research and operations, including receptivity to new research results within the operating arms. There should, of course, also be sufficient overlap in character between the research supported in the two different ways so that there is a continuous flow of information and people between the scientific and operating aspects.

187. A second problem of co-ordination is not covered fully by the preceding discussion. This is the problem of co-ordination in planning and overall goal definition between the various sectors. For example, planning for transportation, urban development, energy policy, and environmental protection all intersect in land-use planning. Indeed as the complexity of our societies grows, the concept of multi-purpose planning for the utilisation of resources common to several sectoral functions becomes increasingly important. In this sense, science is only one such resource, and the concept of a staff function for other common resources must be extended. There are strong reasons to believe that the planning function for common resources of many different kinds should develop within a single new type of staff agency - an agency with projection, forecasting, and analysis functions rather than just a co-ordinating agency for science and technology The argument for this is that planning usually has a heavy scientific component and that consequently it may function most effectively in a scientific atmosphere. There is certainly scope for a great deal of innovation and experimentation in this sort of staff function, which is relatively unknown in governments. We believe that OECD could play an important role in stimulating such experimentation and in assembling comparative information on the results.

Innovation in the Economy and Society

188. Whatever the particular character of organisation for the implementation of policies - national and international - may turn out to be, successful innovation will always depend to a large extent on the strength and coherence of the whole range of scientific and technological activities, on the ability of the education system to produce new scientists and stimulate social interest in scientific activity, on an adequate institutional infra-structure, and on a competitive environment.

The unity of science and technology

189. All scientific and technological activities from "pure" research to the development of prototypes can be regarded as a continuum within which meaningful lines of demarcation cannot be drawn, even though different policies are appropriate at different points along the continuum.

190. However, innovation does not result from a linear sequence passing through all the stages of this continuum, automatically converting new knowledge into new applications.

191. It must never be forgotten that scientists motivated exclusively by their own curiosity and without regard to any particular social direction, have rendered services to humanity more than justifying the cost of the resources made available to them. The support of research must be informed by the realization that the objectives of the sponsor and those of the researcher may be quite different and yet both may be well served in the long run by the results. Research is not a hierarchical activity in which purposes are generated at the top and gradually refined and made more specific as they filter down to the level of the bench worker.

192. During the decade of the 1960's a part of the political support for strong programmes of fundamental research, especially in the physical sciences, derived from emphasis in many Member countries on high-technology space and defence programmes and from a consequent association between high scientific capability in general and high political influence and prestige in international interactions. Because national concerns are now undergoing a reorientation away from these high-technology activities, policies for basic science are also coming under serious question. The shift in emphasis implies neither less basic research to meet society's demands, nor as much change in the content and scientific objectives of fundamental research as might be supposed at first sight. There will be a new set of linkages both within science and between science and social goals. How to establish these new linkages and break some of the older ones without sacrificing the dynamism of science itself is one of the difficult tasks of science policy. Because of the generality of basic science and the fact that a given result may be used and re-used in many different applications and social contexts, and because of the increasingly strong internal linkages and interdependencies throughout the entire structure of science, advances are required in many different fields in order to secure advances in the areas most obviously relevant to particular defined goals. Medicine depends on physics and engineering. The social sciences depend on mathematics, statistics, and computer science. Abstract concepts have applicability through a disparate range of subject matter. Thus, however much science is ultimately to be applied, it must have autonomy in the construction of conceptual schemes for their own sake as an essential condition for any applied impact it may have in the long run.

193. Science and technology increasingly complement and interpenetrate each other. The one affords the other a testing ground for training and for the subsequent tempering of people and concepts. This process of reciprocal enrichment cannot be minutely organised. It can be effectively expedited only by

breaking down the mental, social, and political barriers to exchange. It is particularly between academic, industrial, and governmental scientific institutions that effective interlocking should encourage the circulation of ideas, people, and results. To this end, government action should particularly aim at eliminating differences in the status of research workers in the different sectors, as in diversity of pension schemes or regulations relating to job security, which often hamper mobility. These differences lead to rifts within the scientific community, and they could be diminished without in any way detracting from the specific character of each type of institution.

194. Up to now, innovation has in practice mainly affected the sectors of agriculture, transport, and industry. It is becoming increasingly necessary to bring comparable efforts to bear on the mechanisms and methods of other parts of the tertiary sector. Applied to the services sector, most innovations would necessarily comprise a strong purely social and administrative element, for the improvement of methods and practices as well as of equipment.

The human resources: education

195. Government intervention should be concerned with ensuring the provision of sufficient human resources through education and a continuing flow of new fundamental scientific knowledge. This special responsibility becomes more essential in view of the widening range of skills and basic knowledge required by innovation, and the uncertainty surrounding any attempts to forecast future needs in this sphere. This task is further complicated by the almost universal crisis at present besetting educational systems.

196. During the past 10 years the number of students entering higher education has multiplied very rapidly in all industrialized countries, and in most countries the number of post-graduate students has increased even faster. This increase has been mainly a response to social pressures, that is to say, to the demand for higher levels of educational attainment as a means of social betterment and of general ability to cope with life in modern society. (1)

197. As in the past, the development of higher education has been governed largely by the aspirations of the students themselves, and of their families, and has depended more on national tradition than on employment prospects or on conscious analysis of the future needs of society. Furthermore, the nature of the education process itself has changed very little in response to the rising number and greater variety of students it must now accommodate. All this has contributed to the widespread crisis in higher education in the advanced countries - a crisis marked by student unrest, increasing public disenchantment with the higher-education system and increasing public reluctance to pay its rapidly rising costs.

(1) See Development of Higher Education 1950-1967, Statistical Survey, OECD, Paris 1970 and The Analytical Report, 1971, (nineographed) based on it

198. The crisis in higher education has an impact on national science policy, because one of the main justifications for supporting fundamental research is its role in producing post-graduate scientists and engineers and in maintaining the intellectual vitality of university faculties and keeping them abreast of current scientific progress. By and large, higher education, at both graduate and post-graduate levels, has expanded in conformity with the model of the past, a model contrived for a much more selective and elite clientele, designed to produce a country's professional leaders. While it is true that the demand for people with professional and technical qualifications has grown much faster than the demand for the general labour force in Member countries, the output of the higher-education system has already overtaken, or may shortly overtake, this demand, temporarily amplified as it has been by the need for new teachers in the expanding education system itself, both to staff brand new universities and to enlarge the capacities of existing ones.

199. It seems quite certain that combined demographic, social, and political pressures will prevent any slowdown in the rate of increased intake into the system. The crisis will have to be met rather by internal reforms within a system, allowing wider diversity of output and separating students into a wider variety of streams. An education aimed at producing top-level specialists must give way, in some measure, to parallel streams designed to produce graduates who can fill more general management and administrative posts in industry, government, and other social institutions. The problem of reform is common to all Member countries, but assumes a different aspect in each of them, arising from the special organisation and traditions of its education system. The problem is how to handle large numbers without sacrificing quality and top-level achievements, and how to be selective without stigmatising as failures those who do not succeed in reaching the academic heights. These large numbers must also be handled with greater economic efficiency, and the aspirations and expectations of students matched more realistically to the career possibilities actually open to them in the future.

200. The length of time it takes for any radical change of orientation in education systems, plus the uncertainties inherent in all technological progress, multiply the difficulties of forecasting manpower requirements in narrowly defined existing categories. Too rigid policies for the training of scientific and technical personnel, which attempt to set precise targets for the number of graduates and the content of their training have serious shortcomings. It is not easy to eliminate quantitative or qualitative discrepancies between the supply of and the demand for highly qualified personnel.

201. However, in attempting to reduce quantitative imbalances it would seem essential to avoid a slowing-down or speeding up according to the situation at a given time. This could only

serve to introduce a cyclical process in which a surplus of highly qualified personnel would inevitably be succeeded by a scarcity. A more even development of scientific and technological education is required.

202. More important than trying to regulate the flow of scientists and engineers, and particularly research workers, is concern for the content of their training. Whereas the recent past was characterised by the concept of "maximum specialisation" designed to prepare each individual, from university onwards, for very precisely defined fields, we should now consider more and more carefully the idea of "maximum adaptability". To avoid imposing upon scientific and technical ventures an overall inflexibility in the structure of human resources, thus limiting possibilities for development, we should endeavour to equip prospective researchers with the sort of education that will enable them to move easily from one type of project to another, from one discipline to another, and from research to other forms of activity. Furthermore, only a system of continuing education can make it possible at any stage in a man's career to equip him with the special skills of immediate value made necessary by new technological circumstances. The spread of technological change to new sectors of socio-economic activity should lead to a reappraisal of the aims of education. Its content, too, must be adapted to an era in which technological progress has engendered great uncertainty as to future needs for qualified manpower. The training of research workers, in particular, cannot be subjected to rigid planning. It should be carried out with the utmost flexibility in order to allow for all kinds of adaptation. But it is essential to ensure that signals from the outside world be fed back into the system to facilitate its self-adaptation.

Problems of the industrial sector

203. Sustained by research and education, the innovation process takes place through institutions that may be either public or private and that may or may not be motivated by profit, but are always in one way or another linked with the existence and orientations of a market. In most countries, the business-enterprise sector has been the major performer of the innovation process. In the high-technology fields, the governments have provided the markets.

204. It is, therefore, clear that science policy must be developed partly with reference to an industrial strategy designed to encourage the formation of an economic infrastructure basing its expansion on technological progress. Some countries have been particularly successful in this. Some firms are trying by advanced specialisation, to capture part of the market for technologically advanced products. Other firms, attaining a status of national importance, have become the partners of

governments in the creation of large-scale advanced technological systems, and in some cases they wield an influence in international economic and trade relations.

205. Firms with international operations have existed for some considerable time. Until a few decades ago, they were mainly mining and oil companies or companies exploiting other natural resources of foreign countries. Today the field has widened to embrace a diversity of industrial activities, many of which are characterised by a high technological content.

206. A change is taking place in the nature of the international company, from the trans-national company typically owned and managed in a single country though operating in others, to the "multinational" company, whose capital is so widely spread and its markets so diverse that it cannot be completely identified with any single country. In many respects, however, the transformation is still incomplete: many contemporary "multinational" firms still have predominantly single-nation management.

207. International firms are nevertheless increasingly being used as instruments to create markets of a dimension and complexit that would be unattainable by operating or exporting from a single country only. By operating on a world scale, the company enjoys a volume of international demand that is not only greater in itself but also less liable to wide fluctuations.

208. An increasing part of industrial R & D in the Member countries is carried out by international firms. These firms are becoming an important and effective instrument for transferring and diffusing technology throughout the world. The efficiency of the transfer process is due largely to the complex network of relations linking the parent company to its subsidiarie including the movement of people from one activity to another within the firm. Government transfer mechanisms, especially in the less developed countries, tend to be much slower and much less flexible. The technologies transferred from country to country by these firms are not necessarily the most original in scientific terms, but their economic and industrial importance is considerabl technologies are not transferred in a crude form, but are usually accompanied by a large number of supporting skills that will help to ensure successful marketing.

209. The importance of these transfer mechanisms cannot be overrated. They have been a powerful factor in the world-wide diffusion of technology and have brought important benefits to the recipient countries in economic growth, greater efficiency and new consumer products. On the other hand, there is a clear conflict between the concept of national control of technologies regarded as essential to national security and national economic development and the growing importance of the international corpor tion in high technology industry. This is only one aspect of an

increasing discrepancy between the military and economic implications of new technology and the scope of traditional political units.

210. The transfer and diffusion of new and more efficient technologies are frequently hastened by international firms. Yet it may happen that this process goes beyond the control of government policies in general and of science policy in particular International firms clearly exercise considerable economic and political influence in underdeveloped countries which often have minimum influence on corporate policies of these firms. Such policies may have unforeseen effects on local social economic structures. For example, the too rapid introduction of an automated manufacturing process in competition with less competitive and efficient domestic manufacturing methods might create a problem of labour adjustment and retraining whose costs would have to be borne by the recipient country rather than the company producing the effect. The impact of these firms is also making itself felt even in the most industrialized countries, for instanc in the case of foreign control of industries regarded as critical for the management of national economies.

211. In connection with the transfer and diffusion of technology international firms should be regarded as a constructive force. The evolution towards the truly multinational firm appears to involve fewer political strains. However, the impact of the international firm must be understood if it is not to produce undesirable effects. The existing international economic system does not possess the mechanism for concerting an international response to this new phenomenon. The policy of individual nations towards international firms should be harmonized and the scientifi and technical activities of such firms should be taken into consideration in the formulation of national science policies.

212. Many countries, in attempting to stimulate national industries, have been led to assign publicly funded, large-scale technological projects to local firms. Assumption of these projects, however, has not always been accompanied by the improvement of the competitive position of the firms concerned. This experience may in fact lead to the conclusion that, in respect to the development of the ability to innovate technologically, social processes and attitudes are of more immediate importance than concrete technical and economic results.

213. Competition has played this fundamental role of incentive to development, either through the pressure to reduce production costs or through the need to offer newer and newer products. It has, however, been possible for it to remain effective only within national economies with sufficient resources to tolerate resulting duplications. The elimination of customs barriers, progress in the techniques of transport and communications, and the growing universality of needs are now, however, making

competition more and more international. National governmental expenditures sometimes offer a market protected from the brunt of international competition. Recent changes in the priorities for public expenditures have, however, forced many firms to attempt to diversify their markets and thus to compete more directly with foreign firms. Each national economic system is thus increasingly compelled to match its industrial achievements against those of other countries, and to take vigorous action to advance its internal technological and economic efficiency.

The Management of Technological Progress

214. All technological progress comes at some cost, and some risk is attendant on the introduction or extension of any technology. Technological progress inevitably involves the balancing of risks about benefits; however, a situation exists in which widely different standards are applied in different technological areas. For example, every developed nation accepts an enormous annual death toll from motor-car accidents, but views with great alarm the possible damage from low-level radiation from nuclear power plants.

215. If the sole aim of science policy were to stimulate innovation, this stimulation would know no bounds. But the hopes that industrial societies place in their science policies are more subtle and involve more complex responsibilities.

216. It may appear, sometimes, when the stable equilibrium of society is compromised, that not every innovation is desirable, and that not every desirable innovation spontaneously appears when needed: the random aspect of technological progress seems to threaten man's social and natural environment. It is not, however, technology itself that is to blame for these disruptions, but the manner in which society applies and diffuses it, in view of the impossibility of planning innovation. Change cannot be left to follow the logic of technology alone; society must adapt itself, both to moderate innovation according to needs and to avoi undesirable side-effects.

217. Insofar as it sets itself the prime objective of organising and facilitating the impact of scientific and technological activity on society, science policy manifests itself as the obvious instrument for implementing the necessary interactions between them. This function cannot, however, be satisfactorily discharged unless the issues at stake, and the means and the ends, are much more thoroughly understood.

The directions

218. The efforts made over the last 20 years have led to a better understanding of the way in which innovation comes about and, to some extent, of its influence on the social and economic

environment. The accumulation of this knowledge has thus helped to whet the ambitions of governments to intervene more comprehensively and purposefully in the process. From a policy for research, as practised in the past, they are now gradually turning to the hope of developing a more ambitious science policy, not confined to influencing the supply of or demand for research, but seeking to dominate all scientific and technological progress. Research policy is therefore now seen to be but one of the arms of science policy. The second arm of science policy, the orientation of technological progress, is an absolute condition of effectiveness, without which science policy would be denying itself any possibility of influencing the construction of the future.

219. The past successes of large-scale government programmes have led to some illusions and overstatements concerning the capacity of the research policies of the last decade to effect social, economic, and technological change. It is becoming apparent that the present capacity of society to act deliberately upon itself is limited.

220. Modern industrial societies, a prey to harsh social and economic difficulties, to increasingly rapid change and to a feeling of growing complexity, have come to attribute their problems to the spontaneous and unbridled character of technological progress. They have thus sought to gain greater social control over the processes of decision on research, technological innovation, and the social and economic equilibria.

221. The function of any control mechanism would be to forecast the range of possible effects of technology on society and the natural environment, so as to illuminate society's choices before options are foreclosed by default. It would also be required to explore the new possibilities of satisfying social and economic needs afforded by scientific progress. Finally, it would keep a watch on the evolution of these needs with a view to redefining its aims and refining the goals of society in the light of new knowledge.

222. None of these tasks is radically new. Some forms of technology assessment have been in existence for a long time. For instance, the inspection of pharmaceutical and food products is generally compulsory before they are launched on national markets. Furthermore, the inspection has been extended, in some countries, from their safety to include their efficacy or nutritional value and the validity of their marketing claims. These examples show that our recommendations are partly supported by long-standing administrative and political traditions.

223. These precedents are nevertheless exceptional and affect only particular types of industrial activity and innovation. The three tasks we have just proposed set much more ambitious aims and are designed to establish an assessment process embracing the whole economy and relating the whole of technology to the whole social and natural environment.

224. The search for a mechanism of this kind demands a very strong sense of responsibility for the future on the part of both political authorities and private individuals and organisations. Many of the dangers that it now seems necessary to exorcise would, indeed, if they were ignored, fall with full effect only on future generations.

225. Standard political, social, and economic calculations tend systematically to prefer immediate satisfaction to future equilibrium. The management of progress implies an effort to take into account the future in calculating for the present. Such an effort is not habitual, in part because it is so difficult, but it is increasingly essential to the mastery of technological progress, and must establish itself as the policy for the future.

The means

226. The co-existence of a climate of innovation with structures for the direction and control of the effects of economic and technological change will be possible only with the development of flexible incentives. In most cases, the present state of knowledge is not sufficient to provide a sound basis for the formulation of these incentives, which must be based on extensive understanding of natural, technological, and social phenomena.

227. The key requirement is a wider range of options in the early stage of the innovation process combined with a more sensitive, comprehensive, and rigorous process of choice as the various options progress towards application. This involves deeper consideration and exploration of alternatives at the beginning, with a larger number of checkpoints in the process of selecting options so that vested interests, sunk costs, and professional commitments do not build up a momentum that becomes difficult to reverse. There must be earlier identification of possible difficulties and side effects and a willingness to assign highest priority to research aimed at understanding and quantifying these effects at the expense of the more traditional type of developmental effort. There must also be a more careful technological exploration of other but possibly more costly or more distant alternatives that promise to have significantly less costly side effects. If the process sketched here is followed, it does not necessarily mean a lowered incentive to innovation. What discourages innovation is the high risk of failure due to regulation after a large investment has been made.

If the ground rules are understood at the beginning of the innovation process, it will adapt and generate the research and development in an efficient order of priority with no increase in net risk.

228. The considerations adduced above are illustrated by the problems of the Concorde and the SST. Whether or not it turns out that the salient issues in connection with the fate of these projects has to do with the intensity of the sonic boom, its effect on the human and natural environment, and the possible climatic and health effects of injection of various combustion products into the lower stratosphere, these issues seem to have been treated as a kind of afterthought, problems to be worried about and worked on after the feasibility of a prototype aircraft had been established. The inability to resolve these environmental problems might render the developmental effort on such an aircraft entirely obsolete. It is noteworthy that the research involved in these environmental issues is more fundamental than the research involved in the design of the aircraft configuration and its power plant. It seems that the decision to embark on the SST and the Concorde was made without sufficient consideration of alternative technological pathways to improving air transportation for people. This incompleteness in technologic assessment is not only visible within the air transport field, but also within the wider field of ground transportation, between air terminals and cities. The economic and social costs of this shortcoming of science policy are far from trivial. Technological decisions made in this limited way can cause expenditures of such a size that the economic, social, and political costs of terminating the projects at a late stage become very large.

229. The capability of governments to introduce new, socially oriented technologies, altering traditional lines of technological development, is often less restricted by objective factors, such as competitiveness on international markets, than is commonly assumed. Let us again take the example of air-traffic. A socially oriented technology in this field would have to aim at the production of types of aircraft with low noise levels and without pollutant products. Such a technology would have to be less consumer-oriented, the yardstick not being solely the need of being transported as fast and as economically as possible, but rather socially oriented in the sense that it would take into account the needs of those who are exposed to the technology applied now (e.g., the needs of communities made uninhabitable by the noise and the combustion products of a major international airport).

230. There can be no doubt as to the salability of such a new technology on international markets. The detrimental environmental effects of present air-traffic technology would make political pressures to introduce alternative devices compelling, once such alternative technologies were developed. The introduction of socially oriented technologies of this kind implies

a redefinition of the "technological frontier". Whoever would be the first to develop such a technology would be technologically "ahead", not only in terms of satisfying social needs but also in terms of international economic competition. In fact the "technological gap" between smaller powers and the great powers would be narrowed as soon as the first (and this even within the limitations of their existing R & D budgets) focussed on the development of selected socially oriented technologies.

231. Research on the effects of human activity on the ecology of the earth is manifestly essential to combat the deterioration of the environment resulting from long neglect of its possible consequences: in the present state of knowledge this deterioration is, in many cases, irreversible. But it is important to emphasize also that the study of the effects of human activity requires an understanding of the environment in its natural state and of the various dynamic processes that go on naturally. The environment is in a state of complex dynamic equilibrium. Human activities disturb this equilibrium by accelerating some processes and inhibiting others. So, without understanding of the natural equilibrium, there is little hope of measuring and controlling the human perturbations of it. In addition, the study of pollution in the future requires base-line data on the present condition of the environment, which we cannot go back and measure at some future date when we are beginning to suspect deleterious effects. Here again, we find a situation in which a rather fundamental type of oriented research pursued vigorously today will save us enormous headaches and waste of technical resources at some time in the future.

232. Experience and a better understanding of their effects on natural phenomena should make possible in the future more systemati forecasting of the consequences of technological development. This type of assessment, however, must also give attention to the social impact of technology, and will have to rely on a system of indicators.

233. The general aim of technology assessment is to evaluate the social costs of existing civilian and military technologies in the form of pollution, social disruptions, infrastructure costs, etc., to anticipate the probable detrimental effects of new technologies, to devise methods of minimizing these costs, and to evaluate the possible benefits of new or alternative technologies in connection with existing or neglected social needs.

234. It is to be emphasized that technology assessment has a stimulative as well as a regulative aspect. Its purpose is to foster a more balanced development of technology as a whole in relation to social needs, not merely to exercise "birth control" on harmful or threatening technologies. This positive role must be associated with the regulatory one because a part of the

function of assessment is the consideration of a wider range of alternatives than is ordinarily turned up by present market and political mechanisms left to themselves.

235. The first is the most familiar aspect of technology assessment. Numerous studies have been made on major technologies such as automobiles, pesticides, synthetic detergents, and air transportation, and it has been possible to make some rough estimates of the social costs. This type of assessment may at first sight appear relatively simple; yet the evidence can in many cases be very controversial and may raise issues that go beyond the technology under review. Social costs are often highly sensitive to scale of application, and what is wholly beneficial on one scale develops serious disbenefits when applied on a larger scale. The automobile and the highway systems are well-known examples, in relation to air pollution, traffic, and the accident toll.

236. Evaluating any technology almost necessarily means discussing its social and political implications, and in the last analysis touches upon a society's scale of values. Thus technological assessment does not reveal technical solutions, but usually serves to explore and underline various alternative possibilities with large political connotations.

237. The forecasting aspect of technology assessment is complex in itself. The difficulties lie not only in forecasting technological development in the narrow sense, but also in assessing the ways in which social changes will influence the evolution of technology: assumptions about the stage of society 10 or 20 years hence are usually highly questionable. The problem is that neither social change nor technological change are independent variables. They react on each other in surprisingly devious and indirect ways, and one of the consequences of this is that assessment is an art rather than a science - an art to which science has much to contribute, but for which it cannot substitute.

238. Another difficulty is that of identifying the major new technologies whose future interactions with society need to be predicted. New technologies, precisely because they are new, are likely to be of minor importance today, and it is very difficult to identify those that will have the greatest impact 20 or 30 years hence. Furthermore, because of their novelty, there is much less public pressure to subject them to any form of assessment: "problems" are deemed "worthy of solution" only when they have reached crisis proportions. A further difficulty is that harmful side effects often arise not from single technologies, but from interactions of one or more technologies that originally developed quite independently. In studying the impact of technology on society we are concerned with highly non-linear phenomena in which both the effects and the interactions are sensitive to scale of application. It is precisely this nonlinearity that produces the appearance of crisis in many technological impacts.

239. Establishing the necessary research capacity and fostering the development of new institutions responsible for technology assessment is a complex task that will occupy us for many years. However, the real challenge lies elsewhere: technology assessment, if pursued beyond technology as such, raises some very fundamental questions about the industrial and political system, and in particular about the implicit goals of the framework of competition in our market economies and in world trade.

240. While competition certainly enhances economic efficiency and optimizes the division of labour both within national societie and in world trade, it sometimes leads to excessive differentiation of products and services or built-in obsolescence for rather marginal social gains, and in doing so may divert a substantial amount of technical effort in directions having only marginal social return. Examples may be cited in the large number of motor-car models and in frequent model changes, or in the multiplication of drugs differing only microscopically in their therapeutic effects. Also, competition sometimes rewards the least responsible corporate behaviour, while exacting a large social cost in regulation and in alleviating the disbenefits - a cost borne by the firms themselves, by their consumers, and by the social system. The technology that grows excessively through competition may overload the social services and limit personal freedom by requiring heavy legislation. For example, the rising number of motor-cars makes ever-increasing demands on road construction and ever extensive legal regulation to control its use, so that the burden of motor-car accidents, traffic regulation, and safety now threatens to overload the legal system.

241. In every case, those responsible for technology assessment and the authorities responsible for taking decisions on the basis of assessment studies cannot perform satisfactorily without a continuing analysis of the social phenomena directly at issue. Thus, technology assessment is impossible without an assessment of society designed to relate social and economic trends to the technological factors that may have contributed to their formation.

242. The first efforts made by certain Member countries and by some international organisations to work out a system of social indicators attempt to meet these concerns by developing information systems designed to identify social needs and problems, and to measure progress and retrogression in meeting those needs. On the plane of analysis and day-to-day action, these indicators should, in particular, be designed to provide material for the perfection of the incentive mechanisms essential to modulate the activity of the market. They should also subsequently allow for continuous and sensitive evaluation of these incentives in the light of their actual operation. Above all, these indicators should serve as social "early warning systems" permitting the rapid identification and interpretation of new trends that threaten social and economic equilibria.

243. Social indicators should in fact make it possible constantly to measure the degrees of interdependence and of achievement of different policy aims. It is to be hoped that they will make it possible to clarify, and even reveal, the ranges of aims conceivable at any given moment. More generally, social indicators would be indispensable to the assessment of patterns of adjustment or resistance to change, and as a basis for the development of a learning process through which societies could develop new patterns of development.

244. Nevertheless, despite the hopes that can legitimately be placed in perfected social indicators, we cannot refrain from a word of caution against excessive optimism about them. Indicators are, in fact, no more than a technical measuring instrument, and therefore more or less inflexible and lacking in sensitivity when applied in the context of an increasingly shifting and changing social environment. On the other hand, it is this very shifting and changing quality that calls for social indicators and for continuation of their use and refinement.

245. Furthermore, the incidence of production or consumption on the natural, social, and economic environment cannot be interpreted without taking into consideration non-objective factors that present many purely qualitative and contingent aspects. Thus, the value attached to the natural environment varies quantitatively with the economic use made of it, and qualitatively with the new hopes engendered by rising standards of living and expectations. For example, increased recreational use of water, brought about by rising standards, leads to much higher demands on water quality. More and more people seek privacy and seclusion in the countryside: their aspirations are often in conflict with local aspirations for economic development or with overcrowding produced by other recreational activities.

246. It is sometimes possible to deduce the quantitative value that society implicitly imputes to certain a priori unquantifiable variables simply by reference to decisions made under various circumstances. This could then be used as a rough guide for quantification of the same parameter in new but similar circumstances. Nevertheless, excessive reliance on indicators, and attempts to force unquantifiable factors into their mould, could lead to dangerous over-simplification.

The aims

247. The stimulation and control of the process of innovation, based on a better understanding of technological, economic, and social phenomena, cannot go hand in hand unless they result from gradual adjustments in the boundary conditions of the market. This is not to challenge the basic principles of market economics, but some of its processes could be adjusted so that certain economic activities would bear the costs of injurious effects.

on society. In fact, the notion of the "free" market in the past depended on the relative constancy of the artificial but necessary ground rules under which it operated. As one example, the accounting rules by which profits and revenues are computed or taxes assessed are not facts of nature but human constructs. As another illustration, the competitive positions of nuclear and fossil fuel power are most strongly governed by the annual cost imputed to capital investment and quite arbitrary assumptions as to the useful life of plants.

248. The existing rules and sanctions of the market often produce results that run counter to the social ends in view. Thus, for instance, the fact that certain natural resources are free induces industrialists or householders to use them carelessly and extravagantly. We are convinced that these defects can be compensated and that economic life can be ordered so as to take account of a whole series of social, ecological, and other factors that constitute the indispensable elements for improving or preserving the quality of life, which has sometimes been adversely affected by technological progress.

249. Rapidly rising educational levels of the population are creating a demand that work be not only financially but also psychologically rewarding. In the future this may turn out to be a crucial issue in assessment of the technology of production. Some of the present social unrest among students results from an unwillingness to accept the character of the occupations offered by society and a perception that the present occupational structure is determined by the requirements of technology in relation to economic efficiency. To the extent that greater personal fulfilment in work entails a loss of economic efficiency in the traditional sense, the collective goals of society and personal goals may be in conflict. All these considerations also interact with the nature of education and the self-images created by educational experience. Thus a major challenge to science policy in the next decade may prove to be to find new goals for technological and social and institutional innovation that relate to the adaptation of work styles to the psychological needs of individuals rather than, as in the past, the adaptation of man to work styles set by technology and demanded by economic efficiency. This will obviously demand close co-operation between the social and engineering sciences, since knowledge of the true origins of work dissatisfaction is very limited.

250. This cannot happen, however, without an international adjustment of competition. Remodelling the incentive mechanisms of the market means in practice changing the conditions for competition. No country today is sufficiently powerful or isolated economically to apply unilaterally supplementary restraints on its economy. The spread of technical progress has been greatly favoured by the elimination of customs barriers;

but, at the same time, it has led to a growing integration of national economies and has placed competition in the context of a world-wide market. Any attempt to regulate technological progress must take account of this evolution.

251. Thus, the need to co-ordinate the shaping of the technological future with that of the social and economic future must be felt by all nations and met in concert. In fact, although not equally shared among all, the benefits and the disbenefits engendered by technical progress are felt all over the world.

252. It is, moreover, the inequalities in the face of progress that make any attempt to moderate it so vulnerable: obviously, for instance, the developing countries cannot be called upon to divert to the war on pollution the scanty resources available for industrial expansion. Indeed, no effort to mitigate the global disadvantages of progress can be fully successful without a more equal distribution of the benefits. Furthermore, the developed countries should be expected to assume a disproportionate share of the costs of controlling the disbenefits of technology even when these disbenefits accrue to the underdeveloped countries. If DDT should ultimately be banned world-wide because of its contamination of the global oceans, the developed countries may have to assume the differential costs of more costly pest-control techniques in the developing countries.

253. Concerted international action will, however, also be hampered by the varying degrees to which the industrialised countries feel the adverse effects of progress. This is due to some extent to inescapable differences in natural circumstances such as, for example, the incidence of inversion conditions, the amount of sunlight or rainfall, and hydrological characteristics, but must largely be attributed to the differences in social development that have checked the spread of certain environmental nuisances. We nevertheless think that the universal character of the problems at issue should persuade Member countries not to wait for an irreversible deterioration before taking action. We clearly recognise the difficulties of devising measures to cope with this situation, but we think premeditated and gradually assumed sacrifices preferable to a dramatic awakening of conscience and improvised solutions. Such caution in adjustment to change must not, however, be exercised by any central mechanism that would stifle innovation. To be effective it must be built into the socio-economic processes.

254. In the establishment of new policies, we must also take account of the often-well-justified apprehension that environmental or safety regulations will be used as a pretext to influence the balance of trade in favour of the country propounding the regulation. This apprehension is of particular relevance as the developing countries begin to develop manufactured exports or food exports. It constitutes an additional powerful motivation

for setting standards as much as possible on a multinational basis or, at the very least, giving proposed new standards widespread publicity in an international forum so that affected interests have a chance to protest or adjust. Otherwise the environmental issue could become a new instrument of political divisiveness rather than a boon to humanity.

255. In any event, the regulation of technological progress involves an economist cost that is not only that of preserving the quality of life. Science policy has an important role in sharpening the choices available to political decision-makers. Sharpening occurs primarily through more definitive spelling out of the costs and benefits of various alternatives to various groups, but it cannot usurp the place of the political process relative to decisions that commit the future of the community.

256. Even in its mission of assessing the benefits and disbenefits of progress, science policy is in fact merely an instrument at the service of the broader political, economic, and social functions. It cannot lead to the collective moderation of progress unless national and international leaders are firmly determined to make use of it for that purpose.

257. The general preference accorded to the present at the expense of the future in political and economic decisions must therefore yield to greater caution and deliberation. By refining available knowledge, science policy could provide guidelines to be used for this purpose. It cannot soften the harshness of the choices to be made, but, by producing hard and professionally certified evidence, it can do much to make the choices less arbitrary and more publicly acceptable.

PART V

CONCLUSIONS AND RECOMMENDATIONS

258. Two central themes can be discerned in the situation of the OECD countries in the coming decade: (1) economic growth per se is no longer a sufficient overall objective, and (2) further interventions in the working of the market economy will become necessary. Such interventions may take three forms. The first is the alteration of the ground rules and incentives under which the market operates by such devices as taxes, subsidies, and judicial actions to internalise social costs. The second is regulations and standards in relation to such matters as safety, pollution and use of land or other scarce common resources. The third is direct economic activities of government deemed to be sufficiently in the general public interest to warrant supplementing private activities beyond the level that market forces alone would generate. These interventions will affect the allocation of investments and the direction of innovation.

259. The following conclusions and recommendations are addressed to the Member countries as well as to the Organisation as such. We shall first underline the changes likely to be operative in the 1970's for science policy as well as broader policy objectives, and then propose types of studies and activities that we think must be undertaken by the Member countries and by the OECD as an Organisation.

Conclusions

260. The uncertainty and rapid change of social goals are causing and will continue to cause a difficult and sometimes painful readjustment as the scientific establishment strives to respond to new priorities. The leveling off of R & D resource growth is only one consequence of this adjustment. Massive projects in space defence, and associated activities decline, while goals in social areas have not yet been sufficiently crystallised so that they can be related to coherent and focussed technical programmes. Thus unemployed technical manpower is appearing or may appear in some sectors. Until the new social goals have become better crystallised and related to technical and scientific goals, the future demand for scientific and technical manpower will be difficult to forecast, and there is considerable disagreement about the long-term implication of present trends.

261. To blame the deleterious effects of technology on research and development priorities is unwarranted. These effects are, in fact, consequences of broad social and economic policies. Public disillusion with the effects of the application of technology on the quality of life of the individual, which has rubbed off onto science, is likely to increase. At present this disillusionment is manifested mainly in outcries about such

disturbing effects as urban decay, pollution, and displacement of labour. In addition, there is increasing public questioning of the ethical basis of research whose results might be used for the manipulation of the individual or society. Furthermore, the shadow of nuclear warfare and the use of increasingly sophisticated destructive "conventional weapons" still remains. Thus public opinion is focusing on the negative effects rather than the benefits that society enjoys as a result of scientific discovery.

262. It is important to point out that many current problems of society arise from inadequate development of technology for the services sector in comparison with technology developed for the manufacturing sector. The very slow growth of productivity in government services and in the services sector generally, particularly in education and medical care, has been a major cause of inadequate social performance of the economic system in relation to individual and social welfare.

263. Further economic growth may be necessary before the advanced countries can remove residual islands of poverty, improve social services such as public health, education, and urban transportation, and increase their aid to less developed countries. However, it is now recognised that growth as measured by the market alone does not automatically guarantee the best application of the resources created. Thus, emphasis has shifted from growth in increased personal incomes to growth in generating the means necessary for general social development. The new emphasis entails consideration of the qualitative aspects of economic growth and of social influence upon the direction of investment and innovation.

264. There is now recognition that the improvement of the social infrastructure is itself an element of growth, but that, given a certain potential capacity for growth in the economy set primari by the factors of production - including technology - changes in the quality of life will come only at some cost to other consumption, presumably of the more affluent segments of society.

265. In the Member countries, the complex of problems arising from high levels of affluence, concentration of people in urban agglomerations, and the side-effects of technology sets the stage for a shift of public and parliamentary attention toward social objectives. Rising levels of education and the impact of social unrest and violence publicised through world-wide mass communications have increased awareness of the critical issues.

266. The nature of the new problems and their complex interactions represent a challenge to which government, educational and research structures have not yet fully adapted. Our institutions reflect a division of labour within society that is adapted to the achievement of past goals and the meeting of past challenge The new situation demands a different division of labour and new

specialisations and mixes of work skills. Yet each segment of the structure tends to view the new problems from the perspective of old skills and areas of specialisation, doing what comes most naturally from past experience.

267. The present situation produces an overwhelming need to reassess the place of science and of particular areas of science both in cultural terms and as the roots of the technology through which further change, improvement, or deterioration will flow. When social goals are uncertain and changing, it is especially important that their formulation embody the most up-to-date available understanding of the interactions between technology, the economy, social trends, and the quality of the environment. Those responsible for the development of science policy will have to be more clearly involved in the setting of national goals and the priorities between them if the goals are to be realistic and the system of science and technology made able to respond fully and creatively to them. Research will usually be needed to identify interconnections, inconsistencies, and conflicts between goals. Otherwise expenditures may be made inefficiently or for purposes that are obsolete when achieved.

268. The continuation of economic growth and the exigencies of new social goals lead us to expect further massive development of technology, but in a more comprehensive and socially oriented framework than in the past. A certain amount of catch-up may be required to reverse the deterioration that has already occurred in the quality of life. The required technological development and the advancing basic knowledge from which it must derive may demand further increases in R & D effort in the long run.

269. One of the most difficult and perplexing issues of science policy is the proper balance between centralised policies for science and technology considered as a single aggregate, and sectoral policy related to the particular sectors of social or economic policy served by research and development. There is no final resolution of this problem, but any viable system of science policy must involve some blend of centralised and sectoral approach

270. The American system has emphasised the sectoral approach, with total resources being made available to sectors as a whole - e.g., defence, health, agriculture - and the appropriate R & D levels that are profitable for particular sectors which are determined in competition with capital and service expenditures in the same fields. This system tends to work most effectively in a situation in which total resources are increasing and social goals are rather stable and unchanging, so that the sectors are well defined. Thus the American approach appeared very attractive until about 1966. Some other OECD countries have tended to emphasise a centralised approach, with aggregates of R & D funds being sub-allocated to research in support of various sectors. Such a scheme works better than the sectoral approach in a condition of limited total resources when social goals are unstable and changing rapidly.

271. The new tasks faced by science and technology are more complex and multivariant than the old ones, involving economic, social, cultural, and psychological aspects as well as more strictly technical ones. The interweaving of these considerations both in resource-allocation decisions and in execution will be a major challenge to science policy, which can thus no longer be restricted, as is now often the case, to natural science and engineering development. Both utilisation and further build-up of the conceptual and knowledge base of the social sciences will be matters of central concern.

272. Many of the problems, of course, will be managerial and political, and will continue to require mainly the traditional intuitive managerial and political skills that man has always applied in governing himself, rather than applied science. Nevertheless, we will necessarily take advantage of the knowledge, insight, and methodologies of the social sciences increasingly in dealing with the social aspects of problems such as medical care, education, pollution abatement, population policy, technical assistance, as well as national planning in such areas as transportation, housing, and rational land use.

273. The usual governmental responses to the necessity for co-ordination of policy in various sectors are of two kinds. On the administrative side there are interdepartmental co-ordinating committees, usually operating mostly at the top of the structure and at the most general level of policy formulation. Co-ordinatio also takes place through parliamentary processes, particularly through legislative committees and their staffs. Neither mechanis is fully effective. Administrative co-ordinating mechanisms usually do not command sufficient resources or have sufficient control over budgetary allocations to bring about reconciliation of policies over the many different levels of implementation usually required. Co-ordination of policy at the top of the structure often is eroded in the process of implementation at the separated lower levels in the vertical structures involved, and there is little feedback between the various sectors. Legislative bodies usually do not command the necessary sources of information and lack the time and attention necessary for the achievement of coherence.

274. Furthermore, on both the legislative and administrative sides, the need for political accountability to diverse and often conflicting constituencies tends to limit planning time. Consequently, emphasis is placed on short-term reaction to immediately perceived problems rather than on systematic considera tion of longer-term and more remote consequences of policy, especially consequences lying outside the traditional spheres of responsibility of the particular agencies involved.

275. The selection, management, and regulation of technology will pose difficult problems, in part because this is a little-developed field outside the range of strictly economic criteria. Techniques must be developed for the social and cultural, as well as economic, assessment of various technological options and for the discernment of errors and disbenefits implicit in certain directions of commitment. Assessment must take a broad view of technological applications, pointing out how they should fit as complete systems into society and the safe public limits on their use. The lack of such balanced assessments, carried out on a continuing basis over long periods, has permitted the major social disbenefits of technological advances. The control of technology within political systems that encourage competition and pluralism and retain the profit motive represents a major challenge to industry with regard to broadening its motivation. Balance sheets of costs and benefits for particular technologies will call for considerable scientific research effort. International sharing of this effort and comparison of national experience in assessment, insofar as problems are common to many countries, could be especially fruitful. The value of such international effort takes on new importance in the light of the growing relative contribution of multinational firms to the application and spread of technology.

276. Multinational firms play an important role in the diffusion and transfer of technology across the national boundaries of advanced countries and from these countries to the developing countries. The growing power and the high flexibility of multinational firms give rise to problems and conflict between these firms and the host countries, whose authority is often reduced, and especially when the objectives of multinational firms do not agree with the socio-economic goals of the countries in which they operate. This is of particular relevance to science policy because, in some countries, the R & D potential of multinational firms practically dominates the pattern of national science efforts In such circumstances, there is need for a reciprocal understanding between the governments of the host countries and the management of multinational firms, to harmonize the strategies of those firms with the goals of the countries in which they operate.

277. In many countries, science policies have tended to neglect the potential use of science in many sectoral activities. For example, bigger commitments of national R & D capabilities may be required for aid to developing countries, and this may include both efforts within the OECD Member countries on generic problems of underdevelopment and detachment of scientists and engineers to serve overseas.

278. We wish to stress that simple transfer of existing techniques will seldom meet the needs of the less developed countries. Modern techniques must be adapted to their situation. For example, in agriculture, existing strains of cereals and of plants, as well as breeds of cattle, etc., must be adapted to the various condition of soil and climate. Often this requires cross-breeding and a network of local research stations.

279. In all activities, but particularly in industry, public works, and house construction, labour-intensive techniques should be developed because there is abundance of cheap labour but short of capital. A dual economy now often develops, composed of a small capital-intensive industrial sector with large production per man, the rest of the economy having very low levels of production with traditional techniques. Modern but labour-intensive techniques hardly exist, and consequently a large-scale rural exodus is involving a growing number of unemployed people, who are living in bidonvilles under miserable conditions. In the development of appropriate techniques for dealing with such problems, and in the examination of the fields in which they can fruitfully be applied, scientific co-operation between OECD Member countries and developing countries is required. Such assistance should include development of structures and policies and R & D activities and mechanisms for expediting the transfer of technology from advanced countries. It should also include specific suggestions for the opening of markets in the advanced countries for the outputs of labour-intensive industrial production in the developing countries.

280. Other international aspects of science policy are likely to become important with the growing demands on resources and the extension of activities to which new research can contribute. The shift of emphasis towards the solution of social problems will provide many opportunities for scientific co-operation where the immediate competitive difficulties of technological co-operation hardly arise. Moreover, there is a whole series of activities, particularly with regard to fundamental science, requiring large-scale facilities and activities directly under government control, in which international co-operation or even cost-sharing in R & D could provide a considerable increase in the products from the use of limited resources. Such co-operation could take the form of complementarity in the planning and multinational utilisation of national facilities or of actual joint financing of international facilities.

Recommendations

281. The problems we emphasize are common to most of the Member countries, and many of them are unlikely to be resolved in narrow national terms. Thus there is a growing international function with regard to both the discussion and resolution of particular issues and possible co-operative cost-sharing attempts to solve many problems. OECD, as an association of the industrialised market-economy countries, with Members and interests in many parts of the world, is well placed to play the major role in this field, not only because its Member countries, because of their levels of industrialisation, are the first to suffer acutely from many of the present difficulties, but also because they are in a favourable position to work together towards solutions.

Integration of Social, Economic, and Scientific Policies

282. Economic growth has brought in its wake transformations that seem to have made obsolete some of the traditional concepts of economic policy. If, as we believe, growth and technological progress are two aspects of the same phenomenon, we can no longer consider technological progress essentially as an independent variable. Science and technology are an integral part of social and economic development, and we believe that this implies a much closer relationship between policies for science and technology and all socio-economic concerns and governmental responsibilities than has existed in the past.

283. In the shorter term, we urge that national and international economic agencies take greater account of scientific and technologic factors in the implementation of their policies.

284. In view of the fundamental role of technological innovation in economic growth, OECD should continue and deepen its studies of innovation, its structural conditions, its economic motivations, and its scientific and technological components, in order to assist governments in the development of science policies fully geared to the stimulation and guidance of socially acceptable technological progress.

285. Management of the economy has become difficult after a long period of rapid technological progress meaning also rapid economic growth. Economic theory as it exists today is no longer sufficient as a guide. We therefore recommend that the Organisation launch a study on the working of money, fiscal, incomes and labour market policies in a society in which expanding knowledge, acting as a factor of production, increases the demand for both labour and capital by opening up numerous new technical possibilities while at the same time furthering the internationalisation of economic transactions and the formation of organized pressure groups. Such a study would be interdisciplinary, aiming at understanding the interactions of the economic, sociological, and technological aspects of the complex systems of modern industrial economies. It would enable the Organisation to refine and make more adequate its guidance on economic policy where most countries are in disarray for the moment because technological expansion is changing the rules of the game.

286. Technological change may result in severe structural dislocations, resulting from disparities between industrial sectors, between geographic regions, and between different professions and occupations. Both the Organisation and its Member countries should undertake studies on the influence of technological change on such disparities, on labour mobility, and on inflation.

The Satisfaction of Collective Needs

287. The need for more broadly oriented technologies in all highly industrialised societies is evident and will increase as environmental problems become more acute and public awareness of the social costs of existing technological developments and their perspectives continue to grow. A country that developed such socially oriented technologies would be technologically "ahead", not only in terms of satisfying collective needs, but in terms of international economic competition. Such a reorientation of technology policy can therefore serve the smaller powers as a suitable strategy for overcoming the disadvantages accruing from the so-called "technological gap". Governments of Member States should channel their technological policies into areas capable of producing alternative, socially oriented technologies, i.e., technologies capable of directly contributing to the solution of present infrastructural problems, of satisfying so far neglected collective needs, and finally of replacing existing environmentally deleterious technologies.

288. In the social sector, adequate incentives are presently lacking in large part because there is no mechanism corresponding to the market to measure and reward performance; thus operations tend to be measured in terms of inputs rather than outputs. Many of the deficiencies are clearly technological in the classical sense, notably in air-traffic control, anti-pollution technology, ground transportation systems, especially the integration of different mores, postal services, health care delivery, public housing. The Organisation should consider extending its co-operative research activities into areas that relate primarily to productivity in public services sectors.

289. How attitudes towards work and the interrelationship between work and the rest of life interact with technology and might modify future goals of technology are critical questions. They obviously relate closely to educational goals. We recommend that the Organisation attempt to bring together what is known and what is being studied concerning these questions in the Member countries.

The Assessment of Technological Progress

290. There is urgent need for a much more consistent rationale for the balancing of risks and benefits, not only in the sum total of risks and benefits, but also in their allocation among various segments of society. This appropriate field of economic scholarship is in its infancy. It badly needs to be freed from its present emotional overtones, notably in relation to the environment. The Organisation has a major responsibility to stimulate research in this field both on the methodological aspects of the problem and on the comparative study of practices, explicit and implicit, in the Member countries.

Education as a Collective Need

291. Policy for education, especially higher education, has tended to be formulated on the assumption that students will automatically be distributed among fields of study in proportion to the career opportunities that will subsequently be open to them. However, in times of rapidly shifting social priorities, as at present, the time lag between entry into higher education and entry into employment often creates a serious mismatch between the output of the educational system and the career opportunities available. In fact, there is very little understanding of the processes of adjustment of supply and demand for highly educated people. The Organisation has already done pioneering work in this area, but much more needs to be done.

292. Specifically, we recommend that the Organisation's studies include the connection between excessive specialisation and the maladjustments between supply and demand, and ways in which greater flexibility can be introduced into the educational process in order to minimize these maladjustments and increase the adaptability of graduates in switching to new activities. In this connection, the possibilities of periodic continuing education and mid-career "sabbaticals" for specialised personnel in industry and government as well as universities should be more extensively exploited. We further recommend that, in planning for the development of higher-education institutions in the Member countries, effort should be aimed at greater differentiation in teaching approaches, organisation, and research orientation in order to accommodate a wider variety of cognitive styles, and to allow the economies and benefits of greater institutional specialisation. Our recommendations are aimed at increasing the adaptability of graduates to career patterns that will be increasingly subject to change and reorientation in the future. Furthermore, any system of different educational tracks should allow for easy transfer of students between tracks even at fairly advanced stages of their careers.

293. The problem of matching education realistically to possible career opportunities poses a difficult problem for the democratisation of advanced education and the assurance of equality of opportunity for every student, regardless of social and economic background, to compete for the most advanced training opportunities and the highest positions. We recommend that, in all the Member countries, the financing of higher education be designed to assure the greatest possible openness in competition while not creating unrealistic expectations as to the number of places available at the highest levels. Organisation studies on the economics of higher education should be focused on this specific problem.

Planning for Fundamental Research

294. All countries rely on the world output of fundamental research as a basis for new technological developments and for the rational management of technology. Fundamental research is thus an essential element in the total science and technology system, determining the quality of scientific and technical manpower and the standards for applied research and technology. Fundamental research thus has a considerable external economy; therefore each Member country has an obligation to contribute to the world's pool of fundamental knowledge to the extent of its capability. The total level of fundamental research as a proportion of GNP in the Member countries should be maintained, if not increased, as a necessary condition for the continuation of social and technological progress in the future. The present tendency, discernible in some Member countries, to demobilize research capacity is to be deplored.

295. The current shifts in priorities for technological and applied research should not imply less support of basic research to meet society's future needs. In order to contribute to social goals to the maximum degree in the long run, fundamental research must be provided with considerable autonomy in the determination of its own goals and programmes. Nevertheless, changing social goals do imply selective emphasis on new fields, particularly in the general understanding of complex interdependent systems and the sciences that deal with the natural environment from a systems viewpoint.

296. The emphasis on technological assessment and environmental management may require that, in the introduction of new technology, a considerably higher ratio of fundamental and exploratory applied research to development may be needed than in the past, because the forecasting of side-effects requires more fundamental understanding than is provided by the mere demonstration of technical feasibilities and commercial promise. In the Member countries the future needs for technological and environmental assessment should be an important element in planning for the level and orientation of fundamental research, and this planning should be done as far as possible in an international perspective.

297. While a certain amount of national competition in science is a stimulus to excellence, at least the Member countries should be moving away from national competition, especially in big facilities, and towards a more international orientation; this is necessary in order to get the most value out of national scientific investments. In addition, international co-operation in large-scale basic science can set a model for co-operation in other areas and help in some of the international institution building that will be increasingly necessary for the international regulation of technology. This would include consultation by scientists of one country in evaluating research proposals or

planning facilities and programmes in another. International planning of major national facilities for research is therefore increasingly desirable, and it is recommended that OECD's Committee for Science Policy take the initiative in exploring and developing plans for greater co-operation and planning among Member countries in selected areas, especially those requiring large facilities or integrated systems of observation. Another useful undertaking would be the preparation of inventories of major fundamental research facilities and resources, including skilled manpower.

Multinational Firms and Technological Progress

298. The importance of multinational firms, and both the benefits and problems they introduce for national socio-economic policies, warrant continuing study of the socio-economic and technological impact of such firms.

299. To a great extent, the multinational firm has made purely national policies in the economic and even the social sphere obsolescent, and there is therefore a growing need for agreement among the Member countries on the broad objectives of economic and social policy, and for concerting specific actions - harmonizing of corporation laws, pattern laws, collective bargaining, social insurance, monopoly control etc. The Organisation should undertake an intensive study of multinational firms in relation to their research programmes, national science policies, and their effects on the total course of innovation. This was recommended by the last Ministerial Meeting on Science, and was not implemented. Such a study would inevitably raise the kinds of issues discussed in this report relative to multinational firms and the harmonization of national policies.

The Development of Sectoral Policies

300. We have indicated that science policy in the future is likely to require a blend of centralised and sectoral approaches. Sectoral policy is likely to become more important in many fields in which social needs suggest the requirement for a higher level of research and innovative activity. Many of these fields characteristically lie in the area of governmental responsibility, and are defined by high governmental investment, low growth of productivity, and only minor and fragmented research and development efforts. They include such sectors as health care, urban mass transportation, housing, land use, postal services, telecommunications, and solid-waste management. They also include activities that cut horizontally across many sectors, such as environmental protection, or the management and exploration of marine resources. There must be a determined effort to construct long-term forward-looking policies in such fields, in which market incentives to innovation and efficiency are often lacking. As a first step we recommend that the Organisation undertake a series of comprehensive studies of several such sectors, their requirements

for future research and development and for institutional innovation, and the possibilities they offer for the utilization of science and technology. Such studies should take full advantage of the experience gained from similar studies or past practical efforts in the Member countries.

301. While advocating a sectoral approach in these cases, we are also convinced that, without central resources not committed to specific sectors, research programmes derived exclusively from sectoral needs could easily become captive to short-term goals, day-to-day departmental policies, or overly narrow definitions of need. This would result in the exclusion of longer-term and perhaps more fundamental considerations as well as new concepts and definitions of the needs to be served. Accordingly, we recommend that the Member countries, while encouraging the development of sectoral policies and their interactions, should ensure the central availability of a proportion of their research funds for longer-term investigations and studies, which will probe beyond the research programmes planned to meet well-formulated problems of departments and agencies responsible for particular sectors.

International Aspects of Environmental Problems

302. The extent of the effects on international trade equilibrium of national actions on problems of the environment remains to be seen, and will require continuing assessment. Considerable self-restraint on the part of Member countries will be needed with respect to unilateral imposition of standards on the one hand, and aggressive shifting of production to take advantage of lax standards on the other. This may prove to be a particularly touchy problem in relation to multinational companies unless the countries in which they operate adopt a concerted stance towards environmental regulations and standards. The Organisation should keep this problem under surveillance, and this will require close co-ordination of economic, environmental, and science policy groups.

303. In the consideration of issues and the application of standards relating to the environment, socio-economic and technical aspects cannot be considered separately. Although environmental-control policies might be primarily economic and legal in the short term, they cannot be formulated independently of a knowledge of future technological prospects and possibilities, for example, for pollution control, for less-polluting manufacturing processes, or for new power sources. These considerations should be brought to the attention of the OECD Environment Committee with a view to ensuring that technological aspects are fully appreciated in the determination of tolerance levels or control mechanisms as well as in the design of improved technologies.

304. Many environmental problems are global in nature and require international collaboration, both in assessing the extent of the problems and in taking remedial action. This is particularly true with respect to certain aspects of atmospheric pollution, the pollution of international waterways, and the contamination of the oceans by pesticides, fertilizers, petroleum products, and radioactive wastes. The technical character of these problems is often not fully understood, and monitoring systems are insufficient to determine what is happening. Since monitoring systems can become very expensive, there is an urgent need to develop a better technico-economic rationale for what to monitor, when and where, in relation to the time-urgency of various contaminant problems, the availability and prospects of the necessary technology, and the contribution of each monitoring station to the global assessment. We therefore recommend that the Organisation should perform a central role in assembling authoritative information in this general field, serving as a central clearing-house for compiling and evaluating such information, taking full advantage of the activities of other international groups, both official and unofficial. Emphasis should be given to the preparation of authoritative policy-oriented status reports that can be readily understood by policy-makers.

The Social Sciences and Policy

305. The needs of the next decade for a more rational and socially acceptable approach to the application of technology require evaluation of various technological options. Better techniques are required to measure and understand the incidence of the costs and benefits of technology among the various social and economic participants involved; an important prerequisite for this will be adequate information on economic and social trends and impacts. Increasingly sophisticated social indicators should be evolved to monitor these trends and impacts, and to provide a system of "early warning" of growing imbalances, social disbenefits, dissatisfactions, and emerging social needs. Major effort should be stimulated to devise social indicators that will permit social components to be fully taken into account when evaluating cost and benefit in technological innovation.

306. Social indicators, however, if they are to be fully useful, must be formulated in such a way that public and private administrations can draw coherent and valid policy conclusions from them. Comparative studies between countries and the sharing of national insights and research results may have considerable advantages to offer in this regard. Parochial national biases and cultural traditions can often be better perceived through such a shared approach. For these reasons, we recommend that the Organisation take the leadership in stimulating the development of the social sciences as tools of policy on a multinational basis, much as it has already done in the field of economic policy.

307. In particular, the Organisation should ensure that social aspects are fully taken into account in the study of specific sectoral policies. Governments should include social scientists on central and sectoral policy councils, both to take advantage of new research inputs and to involve social science leaders in policy-making. Creation of effective career patterns in sociology and allied disciplines should be stimulated through better research funding and institution building. The Organisation, through its Education Committee, should assist restructuring of social sciences education, with special attention to producing social scientists able to translate knowledge into practice.

Science Policy and General Planning

308. The problems faced in government decisions are characterised by increasing interconnectedness of the various sectors of policy. Policies formulated for one sector of government responsibility may have important consequences, especially in the longer run, for the achievement of goals that lie in other spheres of responsibility. This interconnectedness of policy is incompatible with the purely vertical bureaucratic structures characteristic of most government organisations. Horizontal connections between these vertical structures at several different levels become necessary.

309. These considerations are especially relevant for science policy for two reasons. First, science and technology are inherent future-oriented and long-range activities and they cannot respond very effectively to goals that constantly change with political fashions or with shifts in public attention. Second, long-range planning for all the many interacting sectors of government responsibility demands a base of knowledge and data that can be acquired and interpreted only through science, including the social sciences. The acquisition of this knowledge itself requires planning beyond the time horizons of traditional political thinking. Thus science policy and general long-range social and economic planning are closely bound up with each other and both require the same types of thinking and perspective. Policies for science, technology, education, public health, economic development, social welfare, and public services must be closely co-ordinated.

310. The need for effective co-ordination of policies, and for institutional arrangements capable of planning and assuring that co-ordination, leads us to recommend creation of a governmental mechanism, operating under specific authorisation and full support of the head of government, with responsibility for investigation of long-range policy issues. This would involve use of all available sources of information and expertise on science, technology, economic, and social trends, and would be closely related to science policy. The most important characterist of this mechanism should be freedom - as far as possible in a

politically accountable system - from the pressures of short-range problems within the time periods of political terms in office.

311. In order to bring the course of economic development, and particularly technological progress, into more satisfactory relationship to community needs and aspirations, each government should establish, at Ministerial level or in a manner independent of the Executive, a special structure that would be responsible for anticipating the likely effects, threatening or beneficial, of technological initiatives and developments. Such a structure would call upon the resources of industry, the government, and the universities in support of its operation, and would specifically seek assistance from all scientific disciplines.

312. In general, we feel that governments would benefit from exploration of and experimentation with their operating structures, in ways that would correspond to staff functions within industry that cut across operating departmental lines, to achieve more effective horizontal co-ordination.

Science and Underdevelopment

313. The needs of the developing countries for science and technology are undoubtedly different from those of the developed countries. National science and technology policies within the developed countries should therefore be formulated with attention to the particular situation of those countries. We recommend that problems relating to science, technology, and underdevelopment be considered by Member countries as an integral part of their national science and technology policies.

314. The Organisation should make an inventory of the activities of its Member countries in science and technology in terms of their relevance to underdevelopment. We furthermore believe that the developed countries ought, as a matter of conscious and explicit policy, to devote a certain fraction of their R & D activities to problems relevant to underdevelopment, and consider that a more rigorous inventory of present science activities should permit a more fruitful discussion than at present with respect to the controversial question of percentages of expenditure. This is a field in which co-operation between Member countries should be extensively developed. The inventory should be seen as a first step towards this. The Organisation should be requested to make any further studies required and formulate recommendations to Member governments in view of such co-operation. Policies should be developed in two directions: (1) fostering in the less developed countries the development of indigenous capability in science and technology relevant to the socio-economic situation of those countries, and (2) formulating research programmes in favour of the developing countries in the laboratories of the advanced countries, as a part of science policy.

315. It is of major concern to us that the recommendations made as from 1965 by the United Nations Advisory Committee on the Application of Science and Technology to development problems have had little effect. We suggest that discussions be held in the Organisation between Member countries participating in ECOSOC work to determine what steps should be taken to follow up the ECOSOC recommendations and, more specifically, those contained in The World Plan of Action (1971).

316. Only by creating institutions in the developing countries themselves does it seem possible, on the one hand, to mitigate the brain drain, and, on the other hand, to become sufficiently close to the particular prevailing economic and social environments to respond to their real research and development needs. We recommend a pooling of advanced-country resources with this aim in view, and stress in all events the value of centralising knowledge of these actions to ensure that, so far as possible, they fit in with an overall plan of international action for the installation of a network of centres of research and advanced studies in the developing countries.

317. The developing countries need to draw as deeply as possible on the "stock" of scientific and technical knowledge existing throughout the world, to avoid duplication, and, in some cases, to gain valuable time and to develop their own research activities on the basis of activities already existing or in process elsewhere. Some of the obstacles to transfer are deep-rooted in the economic and social conditions of the countries concerned and can be overcome only in the course of the economic development process itself. There are others, however, of a less fundamental nature, on which direct action is possible in co-operation with the advanced countries. We believe the Organisation should examine the present situation with regard to the following:

- aid in creating in the developing countries technical information-evaluation centres manned and organised by specialists capable of informing themselves of technological development abroad and of advising on the importation of technologies;

- fostering within the developing countries information banks of value for the specific needs of research on the Third World;

- the availability of training assignments and visits by specialists from the Third World to centres of excellence in their own disciplines in the advanced countries, to assure them of frequent consultation, without thereby inducing them to quit their own countries.

318. We recommend to governments that they organise formal arrangements permitting scientists and engineers from developed countries to spend periods of time in developing countries both to provide technical assistance and education, in situ, and to familiarise themselves with problems and conditions. This could be an important transfer mechanism.

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Alexander KING, C.B.E., is Director-General for Scientific Affairs, OECD. He was Senior Lecturer, Imperial College (until 1941), recipient of the Harrison Prize, Chemical Society (1939), Head of the United Kingdom Scientific Mission, Washington, and Scientifif Attaché, British Embassy, Washington (1943-47); Chief Scientist in charge of Intelligence and Overseas Divisions, Department of Scientific and Industrial Research, London (1950-57); Chairman, Productivity and Applied Research Committee of the Organisation for European Co-operation (1951-57); Director, O.E.E.C., Office of Scientific and Technical Personnel (1958-61). Among his publications are English-German Chemical Terminology and numerous articles on national and international aspects of science policy.

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Helmsmen Peer Ahead

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A BRAVE and mercifully succinct account of how science and technology may be more closely geared to social, as distinct from economic, progress has now been published by an *ad hoc* committee of the OECD under Dr Harvey Brooks, dean of engineering at Harvard University. The original intention was that the committee should attempt to identify current trends in the making of science policy and to suggest how these would influence not merely the institutions which are directly concerned but also society at large. In practice, the committee has done as much as any contemporary organization of comparable weight to show how the goals of science and technology can be made credible in the world of the Doomsday men.

The committee says that in the seventies it will be plain to the governments of developed nations that economic growth as such "is no longer a sufficient overall objective" and that it will be necessary, in the planning of industrial policy, to make "further interventions in the working of the market economy". What the committee implies is that in spite of past successes and future undeniable promises, science and technology must increasingly be judged by the quality of their contribution to society as well as by the degree to which they contribute towards prosperity.

On economic growth, for example, the committee says that although most OECD governments expect that economic growth in the 1970s will be comparable with that in the past decade, "as growth is taken more for granted" inflationary pressures will be increased by the greater competition of interested groups for a larger share of each nation's GNP. At the same time, there will be a need to invest in what is called "social infrastructure" and to demand that societies should be organized in such a way as to be free of internal conflicts. The committee acknowledges that one result may be the risk that developed nations will regard economic growth and the science and technology on which it depends as "sources of disharmony" but that the seventies will be suffused with an unwillingness of the general public to accept that the objective of harmony between people and their environment will necessarily be a costly process.

In the circumstances, the committee comes out staunchly for science and technology as harbingers of constructive and indeed welcome change, but it acknowledges that governments will increasingly seek to influence the way in which industrial output is composed of ingredients with differing social benefit, that the international character of the impact of science and technology will be increasingly preoccupying, with the result that "the management and protection of the global environment will require restraints on national sovereignty for which there is very little precedent"; that there is a danger that contrasts between developed and underdeveloped nations will mean that the "inappropriate technology of advanced nations" is thrust upon the rest of the world; that "gaps" between rich and poor countries will be at once a challenge and an impediment to the exploitation of science and technology; that international corporations will be a constant problem and that these issues will colour the making of science policy in general.

The report of the committee attributes the "difficult and sometimes painful" adjustments of the scientific establishment to new priorities as consequences of uncertainty about and rapid change of social objectives. In the circumstances, it says, there are bound to be serious difficulties in forecasting needs of scientific manpower in particular fields. The committee also says that it is wrong to blame the "deleterious effects of technology" on the choice of priorities in research and development, for these are in fact simply consequences of social and economic policies. At the same time, the committee guesses that "public disillusion" with the effect of technology on the quality of life, at present evident in "outcries" about urban decay, pollution and redundancies, is likely to increase. And what, in any case, is the "ethical basis of research whose results might be used for the manipulation of the individual or society"? The committee's view is that many present discontents stem from the insufficient application of technology to service industries as distinct from manufacturing, that economic growth will in any case be necessary in advanced countries so as to remove "residual islands of poverty" as well as to provide the resources for urgent social development but that advanced nations would increasingly be concerned with the value of economic growth as a means of generating social development rather than increasing personal incomes. In the circumstances, there is "an overwhelming need to reassess" the place of science and its component parts in cultural terms as well as from the point of view of potential productivity.

On the management of science and technology, the committee says that the most perplexing problem is that of deciding between centralization for science and technology and the management of scientific and technical matters as a part of general social and economic policy. The contrast is that between the centralized policies which have recently been adopted by several European nations and the sectorial policy traditional in the United States which is, the committee says, less satisfactory when social goals are changing rapidly. One of the deficiencies of the sectorial approach, the committee says, is that there is a danger that potentially important applications of science and technology to the needs of developing countries will be neglected (but there is a proper warning that it is not easy to transfer technology in this way).

In the circumstances, the committee considers that the OECD may have an important role to play in the evolution of modern science policy because of its existing international connexions. The starting point for this view is that science and technology should be considered integral parts of social and economic policy-making. The committee wishes to see more studies by the OECD of matters such as the process of innovation as well as the operation of the money system, the fiscal system, the incomes policy and the labour market in a technological society. There needs also to be on a national as well as an international basis a closer study of the relationship between technical development and the disparities of prosperity, the mobility of labour and the process of inflation.

The committee asks that governments should deliberately encourage socially valuable technology with the neglect, if necessary, of less desirable work and that there should in particular be an attempt to improve productivity in the public services. OECD itself should become an authority on the problem of how to assess the risks and benefits of particular technical developments and, the committee says, the organization should be prepared to spend money on work of this kind.

In general, the committee considers that education policies usually neglect the differences in the demand for education of particular kinds and the capacity of institutions of education to meet those demands, and goes on to ask that the future development of higher education should be designed so as to provide a more flexible basis for professional work. The committee says that higher education should be "democratized" in the sense of more equal

opportunities for all candidates.

On fundamental research, which the committee regards as "an essential element in the total science and technology system", the committee asks that advanced nations should acknowledge their obligation to provide help for the advancement of fundamental research and that support for basic research should not be diminished in the search for new priorities in the application of science and technology. At the same time, in spite of the advantages of some degree of competition between nations in science, the committee considers that the countries of the OECD at least should be "moving away" from national competition towards closer international collaboration, especially where conspicuous national facilities are concerned.

On the view that most nations will in future require a blend of centralized and sectorial policies for science, the committee argues that the OECD should carry out studies that would inform the making of policy for science and technology in fields such as mass transportation, land use, the postal services and solid waste disposal. Nevertheless, the committee is anxious that no nation should so commit its resources in science and technology to specific fields of interest that money cannot be spared for long-term and basic research. The committee follows a cautious line on the environment but it does ask that individual nations should not act unilaterally in the imposition of standards without calculating the consequences for the pattern of international trade. This, no doubt, is an oblique reference to such things as the determination of the United States Congress to impose restrictions on the effluents from motor car engines.

The committee also asks that the OECD should take a lead in persuading governments to set up suitable machinery for the formulation of science policy. Readers of the report will, however, be at a loss to know whether the OECD is asking for a ministry of science in every member nation by urging the "creation of a governmental mechanism, operating under specific authorization and full support of the head of government, with responsibility for investigation of long-range policy issues". An important part of its argument is that a great deal of the planning of science and technology cuts across the lines on which government departments are at present organized, and that there should be formal machinery for reflecting this pattern. At the same time, the committee takes the view that the OECD in general and national governments in particular should create special machinery for providing technical assistance to developing countries.

WEITZMANN INSTITUTE

Science and Society

from our Special Correspondent

Brussels, June 29

"WE have had the extraordinary experience of having nine of the most experienced scientists for two days on a psychiatric couch." That is how Professor Albert Sabin, President of the Weitzmann Institute of Science, summed up a conference on the impact of science on society, held this week at the Palais de Congress in Brussels. Unfortunately, however, his metaphor was given an unintended meaning by a story related earlier at the conference. It was alleged that the famous mathematician Norbert Weiner spent three days on a psychiatrist's couch relating his problems, at the end of which the psychiatrist confessed his inability to make a diagnosis and Weiner left, none the wiser about his condition. To be sure, the conference lasted for only two days, but an experienced onlooker would probably have found himself in the same unfortunate position as Weiner's psychiatrist.

In spite of the considerable array of talent assembled at the conference (which was arranged by the European Committee of the Weitzmann Institute, and which consisted of about two hundred scientists, including five Nobel Laureates, government planners and industrialists), Sabin himself suggested at the end of the first day's session that the discussion was concerned too much with generalities and not enough with specific issues. Heeding this suggestion, therefore, Professor David Samuel, a biologist engaged on brain research at the Weitzmann Institute in Rehovot, took the discussion of the impact of science on society into the realms of the ethics of brain research. Although he freely admitted that his conclusions and suggestions are not novel, he provided a stimulating discussion of the possibilities open to the scientific community for regulating a specific area of research that has aroused great fears among laymen and also among some scientists. He put forward the suggestion that trends in brain research should be evaluated by the best people concerned, and that a code of ethics should be drawn up to cover the use of human volunteers, the permissible extent of drug trials and the moral aspects of some types of transplants. Such a code would be "not unlike the Hippocratic oath, and it would help guide scientists and show the public that guidelines are being laid down to guard the sanctity of people's minds".

Samuel was, nevertheless, sceptical about most of the horror stories perpetrated by uninformed commentators on the likely possibilities opened up by brain research. He suggested that the idea that electrical stimulation of the brain can be used to change personalities, for example, is not a realistic proposition. Likening the human mind to a telephone system that is a million times more complex than the world telecommunications network, he said that "the complexity of the human mind is a sufficient safeguard against manipulation by a madman or a dictator". Language, culture, personal identity and political ideology are not controllable, he said, but on the other hand, brain research if correctly applied could lead to immensely valuable results.

Some participants did not, however share Samuel's optimism, Professor Aharon Katzir-Katchalsky among them. He told the conference that "there is no question that the public opinion that there is danger in this research has a lot behind it", and he questioned Samuel's suggestion that a value-system for regulating scientific research can come from science alone. But another popular suggestion that from time to time came under fleeting discussion—that a moratorium could be placed on some areas of scientific research—found few supporters. Katchalsky, for example, said, "Nobody knows how to stop research and the truth cannot be kept under control."

The burden of Katchalsky's message to the conference on the first day was that molecular biologists are facing a crisis of conscience equivalent to that faced by nuclear physicists after the atomic bomb—but at least they have the chance to think out the likely consequences of their research before it is too late. Treating the conference to a short survey of the more popular fears and moral problems faced by molecular biologists, he concluded that science has brought about the necessity for coming to grips with international politics, and that scientists should collaborate with people involved in public affairs to bring scientific methods to bear on social problems. But first they must put their own house in order.

In the event, what emerged from the conference was the impression, suggested by Professor Victor Weisskopf in the closing session, that "science is on the defensive". The ten speakers, including Sabin himself, gave the benefit of their 550 years of combined experience to the viewpoint that science, if properly used, is not necessarily an object to be feared or mistrusted. And, as Professor Jean-Jacques Salomon pointed out, "the simple fact that you are met here to discuss the impact of science on society proves no doubt that there is no cause for despair". Nevertheless, many of the participants ventured the opinion during the coffee breaks that a large congress discussing general questions is not necessarily the best forum for stimulating debate.

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INFORMATION TECHNOLOGIES AND PUBLIC POLICY

Abstract

How information technologies are best to serve all Americans is a matter of vital public concern. To guide these technologies properly, public officials need continuing evaluation of policy alternatives. A national perspective, independence of thought and leadership are necessary to meet that need; finding an effective way to do so is difficult, and an important challenge to all of us.

Attachments:

1. Membership of Computer Science and Engineering Board
2. Contributors to Computer Science and Engineering Board
3. Contracts of Computer Science and Engineering Board

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For Presentation at
Fall Joint Computer Conference
Anaheim, California
7 December 1972

INFORMATION TECHNOLOGIES AND PUBLIC POLICY

Mr. Chairman, Ladies and Gentlemen:

I am grateful for the opportunity to speak to this distinguished group of colleagues about some responsibilities we all share.

How information technologies are best to serve all Americans is a matter of vital public concern. To guide these technologies properly, the public and public officials need continuing evaluations of policy alternatives. It takes a national perspective, independence of thought and leadership to meet that need. Fostering these necessary conditions is a difficult but most important challenge for us all.

In describing our concern, I spoke of information technologies in general. In this context, computers cannot be treated in isolation. The various information technologies -- electrical, photographic, print, etc. -- are not just complementary; they are becoming more and more tightly

interwoven and more and more interchangeable. In particular, computer and telecommunications technologies stand on a single scientific and technological base. They are indivisible.

In describing our concern, I spoke of evaluating public policy, not of making it. We must distinguish clearly between our professional responsibility for scientific and technical judgments and public responsibility and authority for policy-making itself.

In describing our concern, I spoke of a national perspective. The interdependence of information technologies requires common attention to common problems. More important, the pervasive uses of information technologies and their importance to every American put them beyond the purview of any single private interest and of any single public agency.

To lend concrete substance to these generalities, let me use four illustrative problems drawn from the experience of the Computer Science and Engineering Board of the National Academy of Sciences.* The first example has to do with the export of computers.

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* Membership list appended.

1. Computer Export Policy

How the United States stands relative to the Soviet Union, Japan and other countries in developing and using computers and allied technologies has been of concern to the Office of Science and Technology in the Executive Office of the President of the United States, to the Department of Defense, to the Department of State and to the Department of Commerce in connection with our export policy. This policy affects every American in such varied terms as defense, goods and services, jobs, profits and prices. Since 1968, when it was formed, the Computer Science and Engineering Board has made several studies for the government in this area, each in response to requests by a consortium of the four agencies I have just mentioned.

Each of these agencies has particular responsibilities, hence particular outlooks and policy preferences. All saw some common need for an objective and broadly based technical judgment of our nation's current standing in computer technology and of the implications of future trends. Judgment of this kind must draw on the best information and the most competent people available anywhere in the public or private sectors.

Whether the subject is export policy, or any other topic of national significance, certain conditions are necessary if the advisory process is to serve the nation - and not just to put the rubber stamp of expertise on the foregone conclusions of a particular government agency or a particular private interest.

These conditions include searching for the facts, whatever their source and they include discretion about information that is sensitive whether for personal, proprietary or security reasons; they include searching for nationally important principles to follow rather than seeking a lowest common denominator of agreement; they include independence enough to withstand pressures to serve only the special interests of a government agency or of a private party; they include independence enough to refuse terms of reference that already define the conclusions and independence enough to suppress no alternative that professional judgment deems significant.

Other examples will suggest further conditions. The next example concerns the interface between computers and communications.

2. Common Carrier/User Interconnection Policy

The Federal Communication Commission's Carterfone decision opened the way for attaching to the telephone network devices not owned by the telephone company. These devices include computers and computer terminals.

In making this decision, the FCC specified that no harm to the telephone network should ensue. The Common Carrier Bureau of the FCC later turned to the Computer Science and Engineering Board for a precise technical analysis of "harm". The Board undertook this task since the accessibility and quality of communication services are of obvious national concern. The Board's findings were published by the National Academy of Sciences as a report entitled "A Technical Analysis of the Common Carrier/User Interconnection Area". This report appeared in June of 1970.

In brief, the Board found that uncontrolled interconnection to the existing network could be harmful and that certain technical limitations on interconnection were in accord with the operational limits of the existing network. It also found that the nature of potential harm and criteria for protecting against it can be specified explicitly enough to be understood and acted upon properly by people with normal technical competencies.

The main conclusion was that technically satisfactory alternatives exist that leave open a wide range of interconnection policy options. Hence, these options can be picked primarily on economic and social grounds rather than on technical grounds. Since 1970, emphasis on the technical aspects of interconnection has abated, but vigorous economic and social arguments continue.

An interesting aspect of this study was that the facts and objective scientific and technical judgments could not be drawn from disinterested people. The best information and the best people available in the country turned out nearly all to be connected with the contending parties. Yet striving for impartiality at the cost of technical competence would be a travesty of a national outlook. The study panel was therefore deliberately made up of people drawn from AT&T, from a small modem manufacturer and from other communications companies. The panel included people from the computer industry and from among users of public and private communication systems.

The conditions necessary for the ensuing analyses to serve the nation included the ability to conduct meetings under conditions of mutual trust and discretion. Trust and discretion were essential to permit gathering and assessing factual information from multiple sources. Trust and discretion were essential to stimulate the free expression of professional judgment among peers capable of distinguishing between party-lining and objectivity, peers also uninhibited in their criticism of one another. The necessary conditions further included scrupulous adherence to genuine technical issues to avoid beclouding, in technical disguise, the due process of public making of public policy.

Our third example is based on a study of library systems.

3. Information Systems Policy

Information technologies are the vital means for giving every American access to the knowledge and to the information that he needs to participate fully in our society. In cooperation with the Council on Library Resources, the Computer Science and Engineering Board undertook to determine what factors, technical and non-technical, have held back delivery on the promises of new information technologies for handling, finding and disseminating recorded knowledge. The resulting report, Libraries and Information Technology - A National System Challenge was published by NAS early in 1972.

The panel found that the primary bar to better national library and information systems is no longer technological feasibility but, rather, organizational and institutional incoherence. It urged national science policy to assume a much more effective role in stimulating public and private actions to weld the present localized and fragmentary efforts into nationally coherent programs.

The report also departed from previous studies in not concentrating solely on scientific information; it took the broader view that our entire society is increasingly dependent on comprehensive and readily available information. Noting that "the hoary ways of libraries are breaking down", the panel made recommendations for developing various information technologies -- including computers as key components -- toward serving the information needs of every American.

Specifically, the panel urged that experience be gained in solving institutional and organizational problems through the development of a pilot system of library and information centers. These centers would manage information coming from many diverse sources and they would provide service to a number of locations.

In the opinion of the panel, information storage media, input and output devices, electrical communication systems and various classes of image-reproduction techniques are available and adequate for pilot activities. However, to assure progress toward a full-scale national network, the panel found a need for improvement in several technical areas. These areas include the cost and performance of large-capacity digital storage technology and the cost of electrical communications. They include data base organization and management -- a critical factor in network development, and microform technology -- which is not yet stable in design standards.

Finally, the panel pointed out that key workers and managers involved in building and operating segments of the national information system need special training to bring together the many fields of knowledge needed for this task.

The conditions found necessary for this panel to serve the nation includedharnessing technologists with librarians, the theoretically-minded with the operations-minded, the cost-conscious with the service-conscious and other improbable but essential combinations; they included striving for a breadth of viewpoint that sees beyond pushing pet technological means, however ill-suited to national ends; they included

ignoring traditional distinctions among academic, for profit and not-for-profit institutions, for neither knowledge nor ignorance and neither integrity nor corruption invariably respect these distinctions, except in self-serving myths.

Our last example is the data bank issue.

4. Policy on Databanks

Debate continues over the impact of computers on the collection and use of personal information about all Americans in public and private files. From its birth, the Board took note of the problem of balance between individual and social needs for information and rights of privacy and due process. The Board concluded that it could best serve the national interest in this area

1. by seeking out the facts through firsthand observations,

2. by interpreting the technological facts in the context of the non-technical factors that shape the use of technology.

3. by estimating trends and developing the future implications of these trands for public policy choices, and

4. by presenting the results to as broad a public as possible.

Classified government files were excluded from this study because of legal limitations on access to these files and, when access is granted, on freedom to publish findings.

The study plan formulated by the Board was accepted and supported by Russell Sage Foundation. The results are described in the report Databanks in a Free Society: Computers, Recordkeeping and Privacy published last month by Quadrangle Books, the publishing arm of the New York Times.

A distinguishing mark of this report is its fascinating first-hand accounts of 14 out of over 50 on-site visits to some of the most advanced computerizing organizations in the country. These include the FBI's National Crime Information Center, the Bank of America, the Social Security Administration, TRW-Credit Data Corporation and the Mormon Church.

The main findings of the study may be summarized as follows:

1. the rapid spread of computer technology is accentuating but not fundamentally altering the problem of balancing necessary collection of personal information with the interests of citizens in personal privacy and due process of law. The major issues were not created by computers and would be major issues for public policy whether or not computers had been invented. There is no technological inexorability here. Policies and practices are controllin

2. Computer data banks are far less advanced in collecting and consolidating information about individuals and less widespread than the public has been led to believe. The most sensitive and subjective information about people still remains mostly in manual files.

3. The next five years will be the critical time for the public to consider and set a balance between the proper and improper uses of computers in record-keeping.

Six main areas of action were identified as priorities for public policy consideration in that five year period: provision for laws giving the right of access for individuals to their own records; setting of confidentiality rules for highly computerized systems; restriction on collection and dissemination of certain data; adoption of effective technological means of safeguarding confidentiality in computer systems; limitation of the use of Social Security numbers as identification; and creation of new types of "information trust" agencies to hold and to manage particularly sensitive files.

Breadth was a condition particularly necessary for that report to serve the nation. The technical issues dealt with could not be confined to some neat and narrow definition of computer science and engineering while still grasping the essential factors. Staffing for that study necessarily drew on computer scientists, economists, journalists, lawyers, political scientists, psychologists and sociologists. It was necessary also to assure that major viewpoints and contrasting positions on the basic issues involved in databanks would influence the planning, research and reporting of the project. A seventeen person National Advisory Group provided this vital influence. This group included Ralph Nader, Congressman Ogden Reid and Nicholas deB. Katzenbach.

Above all, it was necessary to overcome that traditional propensity of the scientific and technological community to mutter into its own beard or whisper into its patrons' ears, in favor of addressing the general public in a loud clear tone.

The need for breadth is not, however, confined to this last example. Breadth is essential to attaining a national perspective that the ordinary private institution, the special interest, the government department do not adopt, but toward which they can contribute. Only through the closest cooperation among experts of the most varied kinds and between these experts and the ablest generalists available in the nation can we begin to discern the whole range of technical alternatives that deserve consideration in important national policy issues. Only this close cooperation can foster that reasoned interplay of conflicting philosophies, opinions or points of view that is necessary to illuminate issues at the interface between science and technology and the public making of public policy.

The pursuit of breadth is a peculiarly difficult undertaking. "It may never have crossed your mind", Donald Barthelme once wrote, "to think that other universes of discourse distinct from your own existed, with people in them, discoursing." It never has crossed most of our minds.

A group of individuals with the most diverse intellectual pedigrees has no effective breadth without an intimate sharing of universes of discourse among its members. Multidisciplinary chit-chat or mere respect between expert and generalist are not sufficient for shared understanding.

Entering comprehendingly into another man's universe of discourse is a shattering experience like stepping through the Looking-Glass into Wonderland. Many never have the experience and others never recover from it. Partitioned academic training not only fails to prepare for it but often actively discourages it. Departments of Computer Science are no exception.

If the experience sounds mystical it is because only experience, not words, can convey it, as the following anecdote will illustrate. Two years ago, I wrote a paper called "Compunications in the National Decision-Making Process". In it, I remarked on the primacy of institutional factors in governing how effectively information technologies might help in decision-making. There were specific references to the balance between filtering of information by subordinates and information overload of their superiors.

Commenting on these remarks, David Packard wrote that had he read my paper a year and a half earlier, before becoming Deputy Secretary of Defense, he would not have appreciated much of it. By then, however, he had seen, he wrote, "case after case and example after example of the kind of problems it addresses."

The wonder therefore is not that it takes time for understanding team work to develop within a group, but rather that it ever develops at all.

Creating a climate that nurtures the many necessary conditions I have listed for serving the nation is as difficult for Federal agencies, educational institutions, professional societies and others as it is for the more openly partisan institutions of our society. Indeed, I am aware of no institution ideal for the purpose.

The National Academy of Sciences has the merit of being an approximation to the ideal by virtue of its Congressional charter. It is, perhaps, a unique approximation. The charter, dating back to the days of Lincoln, requires the Academy to advise the Federal government, on request, in matters of science and technology. In recent years, the charter of the National Academy of Sciences has been interpreted to encompass broader initiatives than in the past on matters of science and technology of concern to all

Americans. As a private body, not part of the government yet chartered by the Congress, the National Academy of Sciences -- given breadth -- has a special potential as a national meeting ground where independence of thought and leadership might flourish.

Besides breadth, one other necessity deserves special mention -- and that is money. The significance of amount of money is self-evident. Here, I wish to stress particularly the quality of money, as it affects the independence and responsibility even of boards, committees or panels whose members are not paid for their services by the National Academy of Sciences.

What I mean by the quality of money, is how the sources of funds for any institution's projects relate to every institution's instinct for self-preservation. An exclusive diet of general contributions can make for independence but it can also make complacent fat cats. Rations limited to specific project money can make for responsibility but they can also make servile hustlers.

I do not know precisely what quality of money gives a proper balance between independence and responsibility on the one hand and fat cat complacency and servile hustling on the other hand. Let me, however, offer one empirical datum. Since its creation, and from many sources whose help I wish to acknowledge here publicly,* the Computer Science and Engineering Board has received about $75,000 in general contributions along with about $650,000 for specific projects. The ratio "specific to general" is roughly 9 to 1.

That ratio has proved unworkable relative to the Computer Science and Engineering Board's collective sense of balance between independence and responsibility and the darker side of the coin. The money has run out. On July 6, 1972, the National Academy of Sciences asked the Computer Science and Engineering Board to bring its currently committed work to orderly completion and to enter a period of "hibernation" pending an appraisal of its future.

There is an obvious moral to this story. I have described to you various conditions that seem necessary in striving for a national perspective in meeting the need for continuing evaluations of public policy alternatives.

---

* List appended

However necessary, these conditions clearly are not in themselves sufficient. Something more is needed; finding this something is a responsibility we all share.

The list of unfinished business is long. Our time here is short, so I shall offer you only a few samples in conclusion. The Computer Science and Engineering Board has made but a meager beginning with the problem of compatibility in hardware and software, and particularly with standardization as one tool for solving this problem. A forum for unfettered discussions of the need for and the nature of standards does not exist. In as fast moving a field as information technologies, it is vital to make broadly informed judgments between standards that are vital, those that are merely helpful and those that are red herrings.

A second item concerns the relation between technological developments and their impact on the applications of information technologies. This is a vast area and one that the Computer Science and Engineering Board has not treated adequately in the past. Ways should be found to make continuing comparisons between current and desired technological trends in order to develop policy guidelines for use by government and industry.

These guidelines should suggest resource allocations aimed at assuring for the United States a strong future base in hardware and software and in competent people.

Last, an item of increasing importance, namely the relation between information technologies and productivity. You are all aware of how the United States is being successfully challenged in many areas by foreign economic competition. To maintain a leading position in the world, American productivity will have to increase at a higher rate than now. Properly employed, information technologies can, I believe, contribute greatly to productivity. Ways should be found to undertake, from a national perspective, a study of the relation between information technologies and productivity in order to find areas of our economy that could most benefit from their effective use. Looking inward, this specifically implies finding ways to build and improve on our own practices in every realm of application; it implies finding ways to carry effective practices over from one realm into others without the chaotic and expensive repetitions of bad experiences that still characterize the diffusion of computer, telecommunications and other information technologies. We owe at least this much to our fellow Americans.

Let us all turn our attention to these tasks and to the many others that will occur to you. Thank you.

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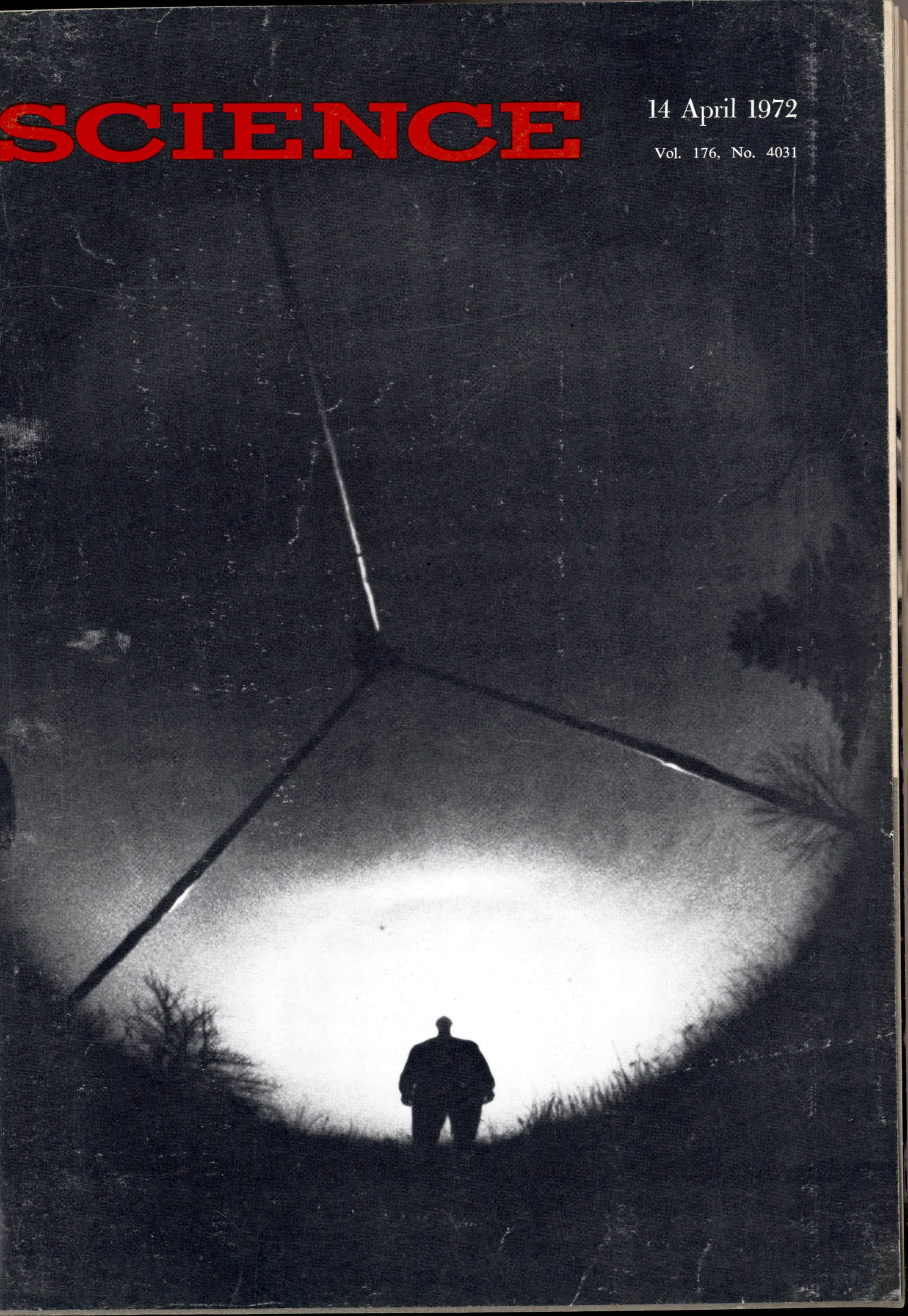

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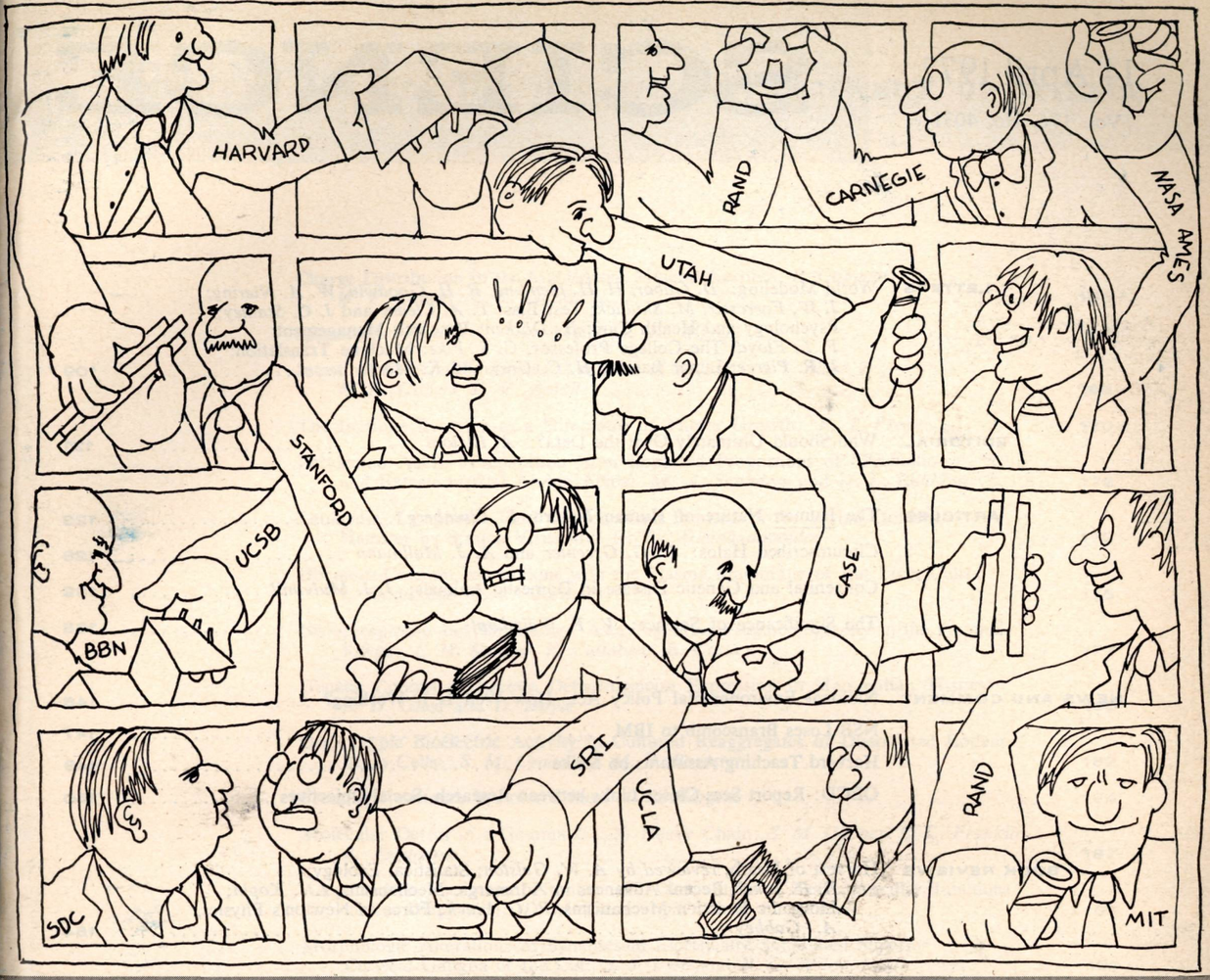

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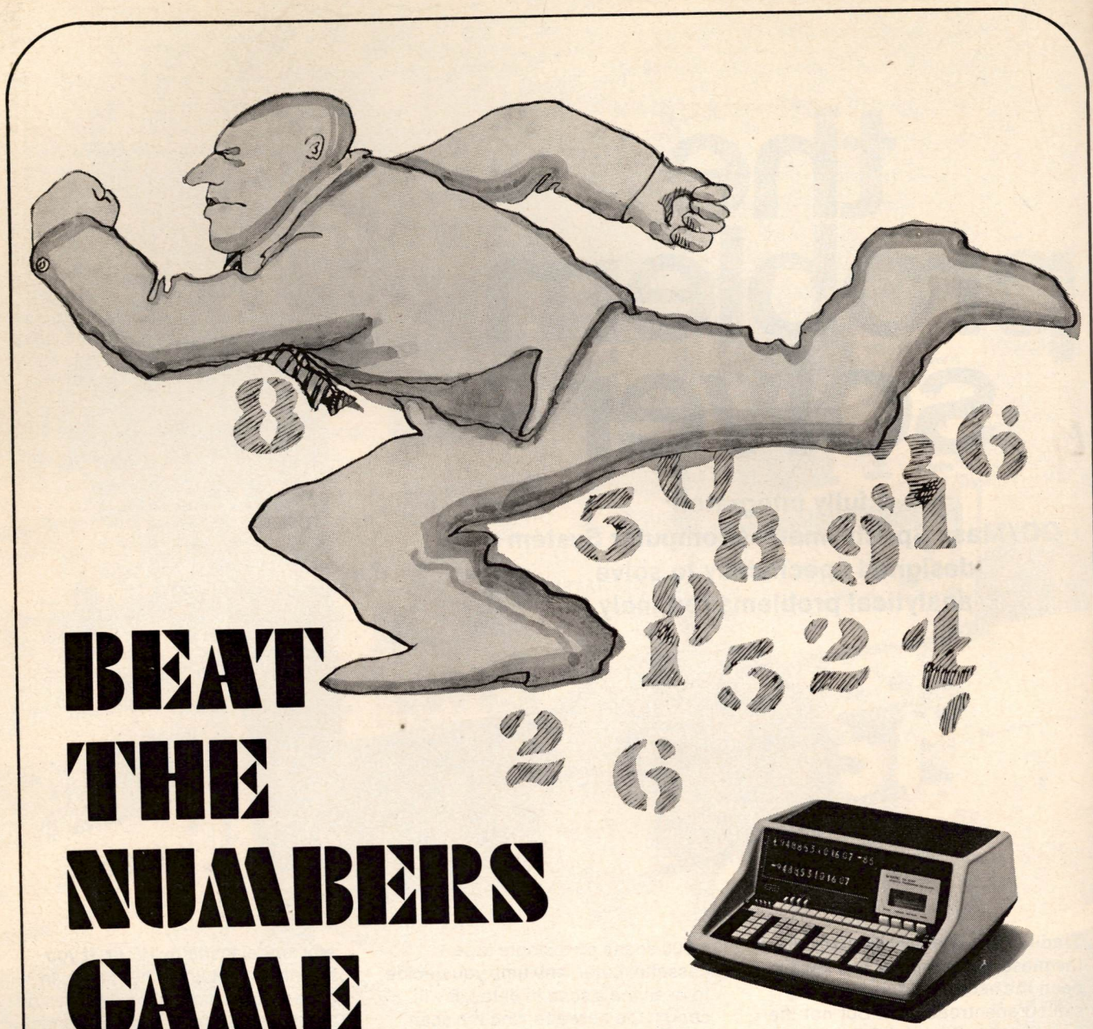

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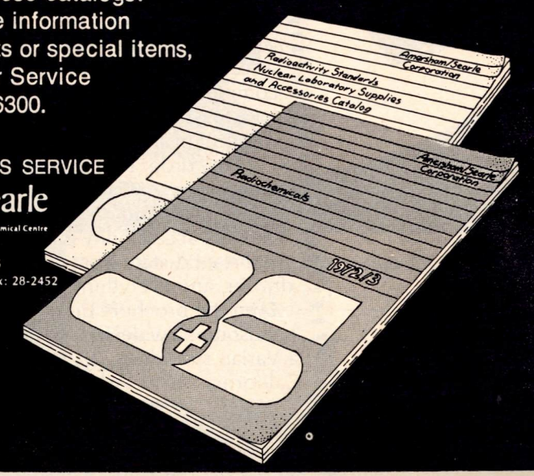

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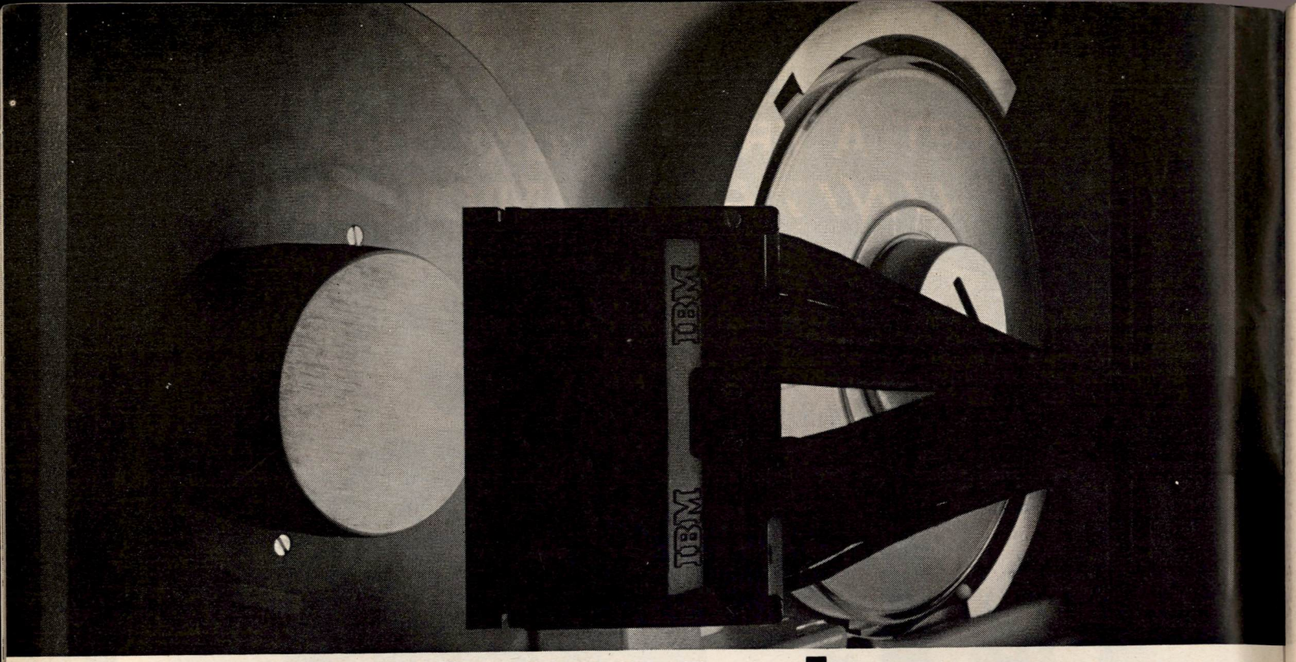

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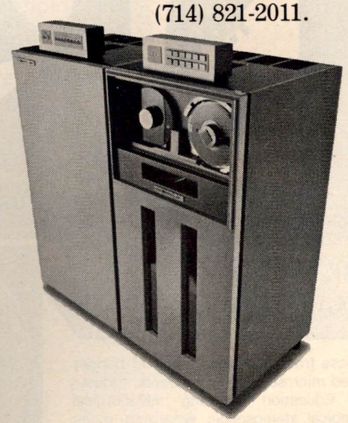

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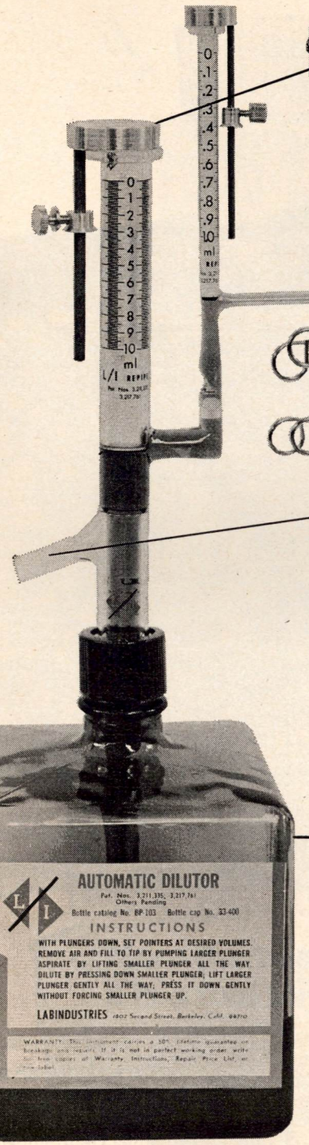

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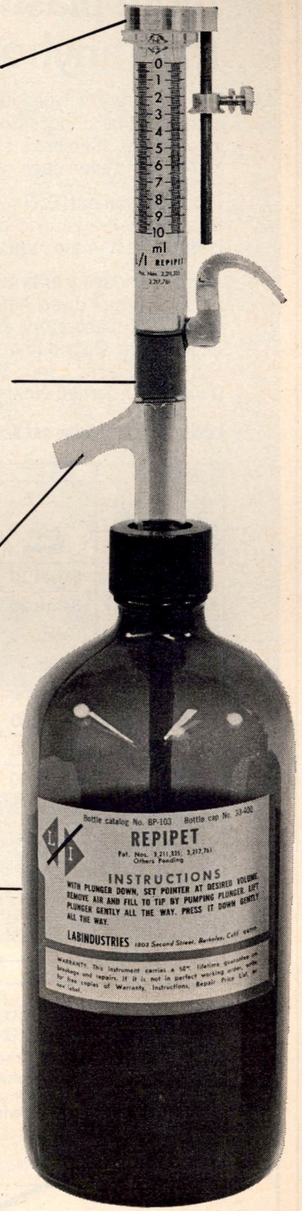

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ANIMALS						CAGES			
Mice	Rats	Hmstrs.	G. Pigs	Gerbils	D. Hmst.	Cage Series	Nominal Dimensions (inches)	Materials	No. Cages Per Standard Rack
	•	•				Series 10	11x8½x6	Available in polystyrene, polypropylene and polycarbonate	60
•		•		•	•	Series 20	11½x7¼x5		84
•					•	Series 30	19x10½x5⅛		36
	•	•		•		Series 40	19x10½x6⅛		30
	•	•		•		Series 50	14⅞x12⅞x6⅝		20
•				•	•	Series 60	13⅞x8⅝x5⅛		72
	•	•	•			Series 70	20x16x8½		15
•				•	•	Series 80	19x8⅞x5⅝		36
•				•	•	Series 120	11½x5¼x5⅛		132
	•	•	•			Series 140	19x10x8		30
•				•	•	Disposable Cage	11½x7¼x5	polystyrene	84
•				•	•	Pre-Bedded Disposable Cage	11½x7¼x5		84

EC-P-4

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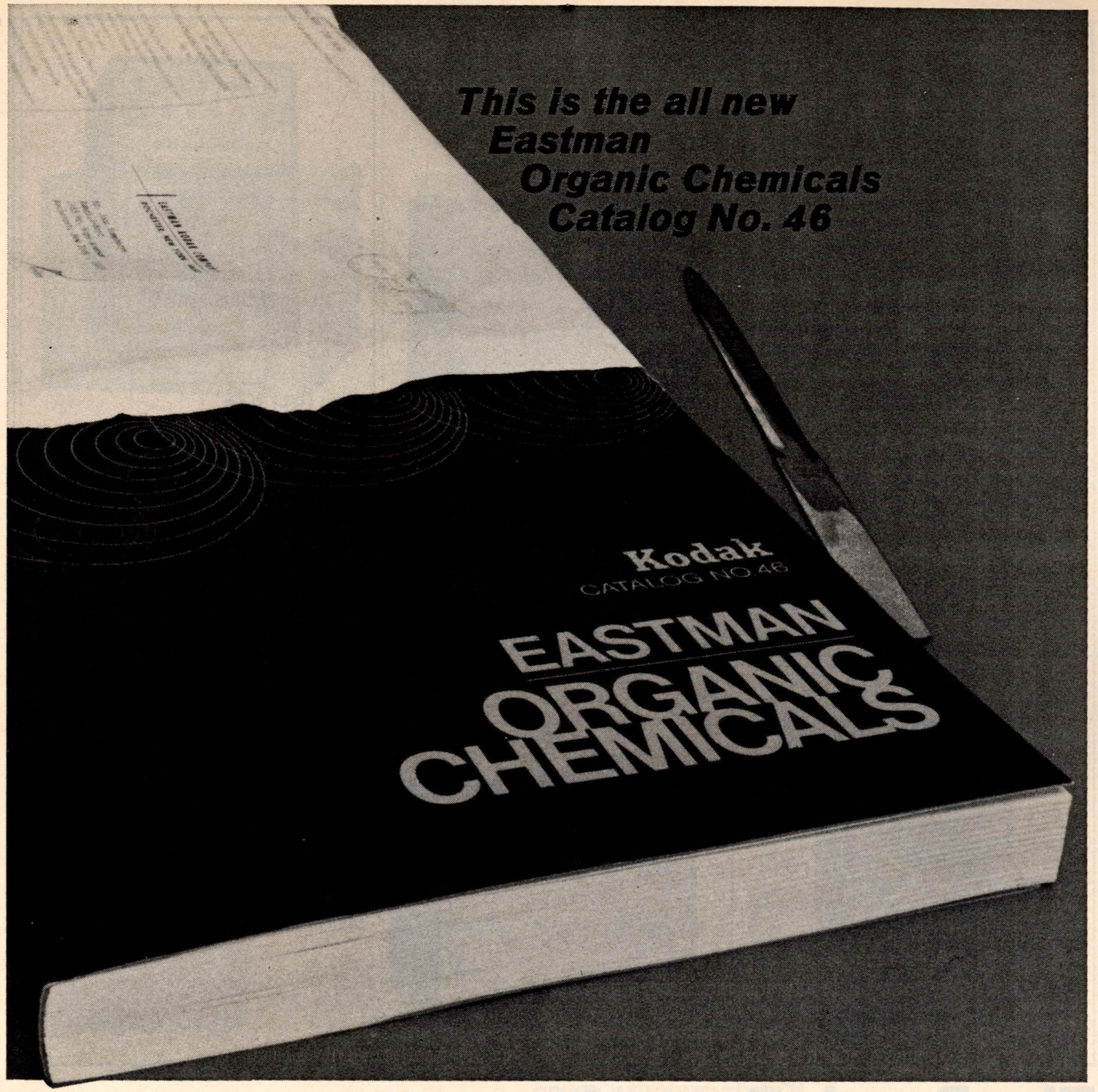

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  - Organic Chemistry
  - Physics and Physical Chemistry

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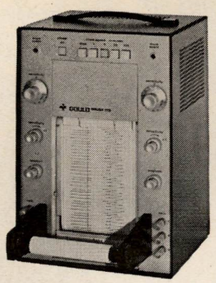
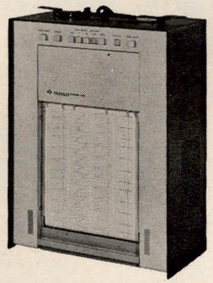


BRUSH 220 2-channel

A versatile, rugged, accurate recorder. Easy to operate, able to withstand inexperienced operator abuse. It weighs only 25 lbs. Comes with built-in preamps with a measurement range from 1mV per division to 500V full scale. 4 pushbutton selected chart speeds from 1 to 125mm/sec. 2-40mm channels, 2 event markers. Frequency response is 40Hz f.s.

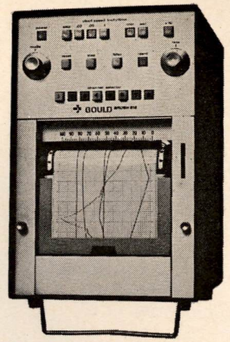
BRUSH 440 4-channel

Maximum versatility at low cost per channel. Exceptional reliability in laboratory or field application. 4-40mm channels and 2 event markers. Frequency response 40Hz, f.s. Sensitivity ±2.5V f.s. Pushbutton selected 8 chart speeds from 1mm/min. to 125mm/sec. Portable, or mobile console. Also available with 2-40mm and 1-80mm channels.



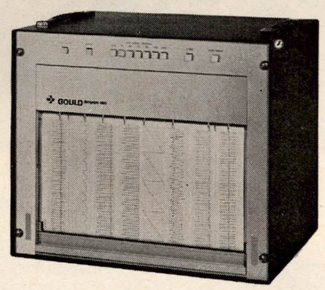
BRUSH 260
6-channel

This rugged recorder handles the bulk of recording tasks with high precision and maximum operator convenience. Built-in preamps provide a measurement range from 1mV per division to 500V full scale, 6-40mm channels and 4 event markers. Frequency response 40Hz f.s. 8 pushbutton selected chart speeds from 1mm/min. to 125mm/sec. Portable, rack or mobile cart mounted.



BRUSH 816
8-channel hi-speed multipoint

This recorder scans and displays up to 8 channels of data adjustable from 2 seconds per point to 16 points per second. Ideal for measuring temperature, pressure and other slow changing variables. Sensitivity ±2.5V f.s. Frequency response: to 1Hz f.s., flat to 35Hz at useable amplitudes. 3 modes of operation. Multipoint, intensified, continuous. Felt tip capillary writing. 12 pushbutton selected chart speeds from 0.02 in/min. to 1 in/sec. Portable and rack mounted models.



BRUSH 480 8-channel

A general purpose recorder suited for a wide range of applications. 8-40mm channels and 2 event markers. Frequency response 40Hz f.s. Sensitivity ±2.5V f.s. 12 pushbutton chart speeds from 0.05 to 200mm/sec. Portable or rack mounted.

The Brush Recorder: performance that's made its mark.

Whether it's all-purpose or high-performance recorders, Brush has an answer for you. Ten different recorders. A choice of 1, 2, 3, 4, 6, or 8 analog channels.

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Another plus for the Brush Recorders is our Metrisite® non-contact servo-loop feedback device. A system so accurate it enforces pen positioning at better than 99½% linearity.

And the Metrisite system also takes care of bothersome maintenance problems. Like dirty pots, wear, cleaning. The Metrisite also eliminates slide wires and all the maintenance problems they cause.

Electronics are all solid-state. And most models come in either portable or rack-mounted versions. And all of them are compatible with our range of signal conditioners. A range wide enough to let you select the conditioning best suited for your measurements.

The Brush Recorders. If you'd like to know more about them, let us know. Contact your nearest Brush Sales Engineer or Representative. Or write for detailed performance information and specifications. Gould Inc., Instrument Systems Division, 3631 Perkins Avenue, Cleveland, Ohio 44114.

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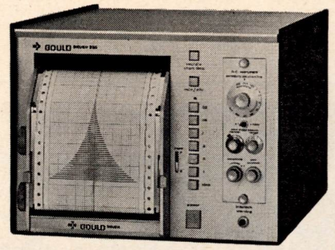
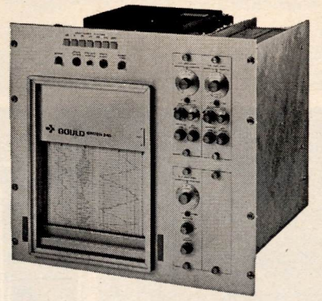


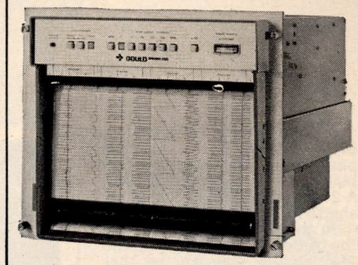
BRUSH 250 single channel

Fast, versatile strip-chart recorder. Frequency response is flat ±2% f.s. from d-c to 10Hz on a full 4½" span. Useable response to 100Hz. Accepts all Brush plug-in preamps. Sensitivity ±2.5V f.s. Detachable chart paper magazine, 12 pushbutton selectable chart speeds from 5 in/sec. to 1/10 of an inch/min. (or 8 days of continuous recording.) Portable or rack mounted.



BRUSH 240 4-channel

Designed for versatility, maximum resolution, and precision. Modular design permits use of interchangeable preamps. Rack, cabinet or cart mounted. Frequency response to 55Hz on 40mm and 35Hz on 80mm channels. 2 event markers. 12 pushbutton chart speeds from 0.05 to 200mm/sec. Sensitivity ±2.5V.



BRUSH 200 8-channel

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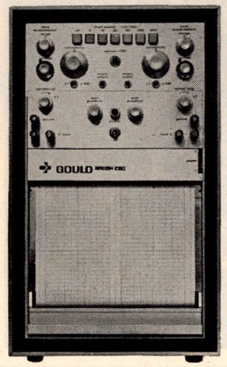

BRUSH 280 2-channel

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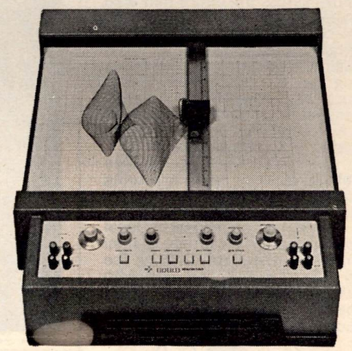


BRUSH 500 X-Y Recorder

A rugged, low-priced recorder, 99.85% linearity. Pressurized ink writing plus electrostatic hold-down. Built-in preamps with a sensitivity range from 100μV/div. to 1.0V/div. 40 inches-per-second writing speed. Portable or rack-mounted.

BRUSH INSTRUMENTS GOULD

The 1957 Hasselblad.
It's enjoying a revival. But not by Hasselblad.

A curious thing is happening in the camera business. Other people are just beginning to build what we discarded in 1957. A 2¼" camera with a focal plane shutter.

At the root of the problem is the sudden recognition of the 2¼" picture size as one that couples large format quality with miniature camera versatility (something that Victor Hasselblad recognized 23 years ago). The trouble is, with everyone rushing in to make 2¼" cameras, quality isn't always a big consideration.

Which is why you should know—before you buy any 2¼" camera—why Hasselblad changed from a focal plane to a leaf shutter back in 1957.

FOCAL PLANE SHUTTER

The focal plane shutter has to move across the entire film area, exposing the negative piece by piece, through a travelling slit. When the subject is moving parallel to the film plane, like a moving car, the position of the subject has changed by the time the last slit is exposed. This time lag can create distortion—an elongated or compressed car.

The same thing happens when taking pictures from a moving car or plane. The landscape tends to appear elongated.

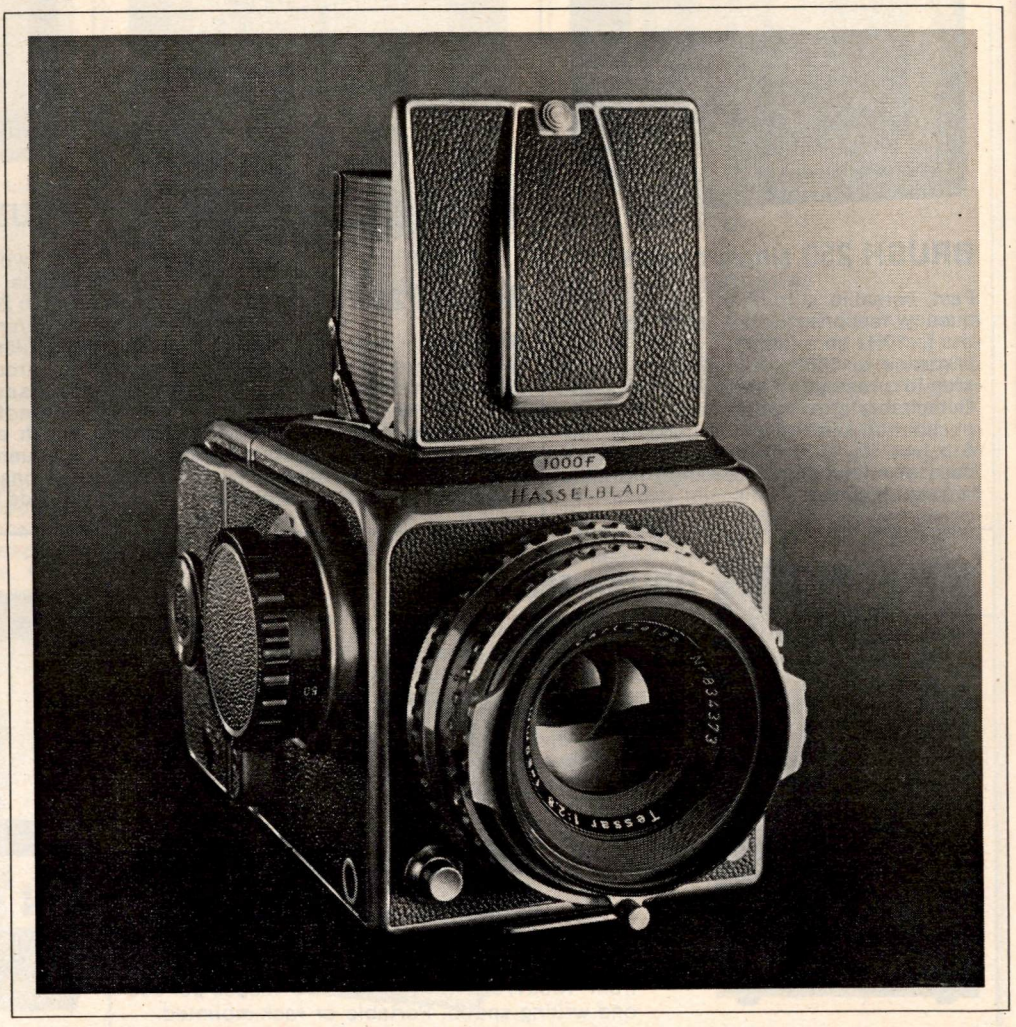
In 35mm photography, focal plane shutter distortion is minimized by the short distance the shutter has to travel. But with 2¼" cameras, where the shutter has to travel farther, the distortion becomes more noticeable.

LEAF SHUTTER

The leaf shutter, on the other hand (which we call a Synchro-Compur shutter in the Hasselblad) exposes the entire negative area all at once. Which makes it a much more accurate and desirable shutter.

The focal plane shutter has another considerable disadvantage. It can only be synchronized with electronic flash at very low shutter speeds. Which makes it all but useless with strobe for action and sports photography. (At higher shutter speeds, only a strip of the film would get exposed. At slower speeds you end up with ghost images.)

These problems are overcome by the leaf shutter which can be synchronized with all kinds of flash at all speeds and apertures (giving complete control over depth of field and background brightness). Making the leaf shutter far more versatile and useful to virtually every photographer.



So in 1957, Hasselblad carefully weighed the pros and cons of both shutter systems and decided to change over from the focal plane to the leaf shutter. We had to increase the camera price to do so, because the leaf shutter is a more complex, sophisticated mechanism. But the objective was to build the best camera possible, without being forced to compromise through economic necessity.

We then developed a full line of ten interchangeable lenses, each with its own leaf shutter mounted between the lens elements next to the diaphragm, in the most optically ideal position.

We increased the number of interchangeable film magazines to a total of six, providing a wide variety of different capacities and formats.

We added many accessories, including a microscope shutter and adapter, a gunstock telephoto lens mount, and a prism viewfinder with exposure meter. Giving greater flexibility to what was already the most flexible camera system. Leading NASA to choose Hasselblad as the space camera, using it aboard Mercury and Gemini flights, taking it to the moon on the Apollo flights, and for use on Skylab orbiting laboratories.

Many features of the 1957 Hasselblad were well worth copying. In fact we've copied many of them ourselves. But we also knew what not to copy. With the result that most 2¼" cameras now employ the shutter system we abandoned 14 years ago.

Of course, if price is a consideration, you'll have to select a camera with a less costly focal plane shutter. But before you buy a new imitation of the old 1957 Hasselblad, look into the used camera ads. You can probably pick up the real thing for less.

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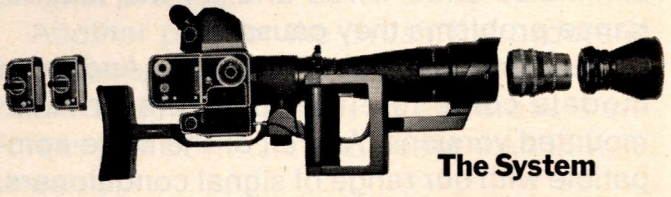

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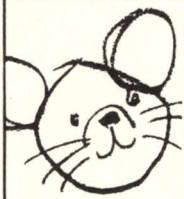

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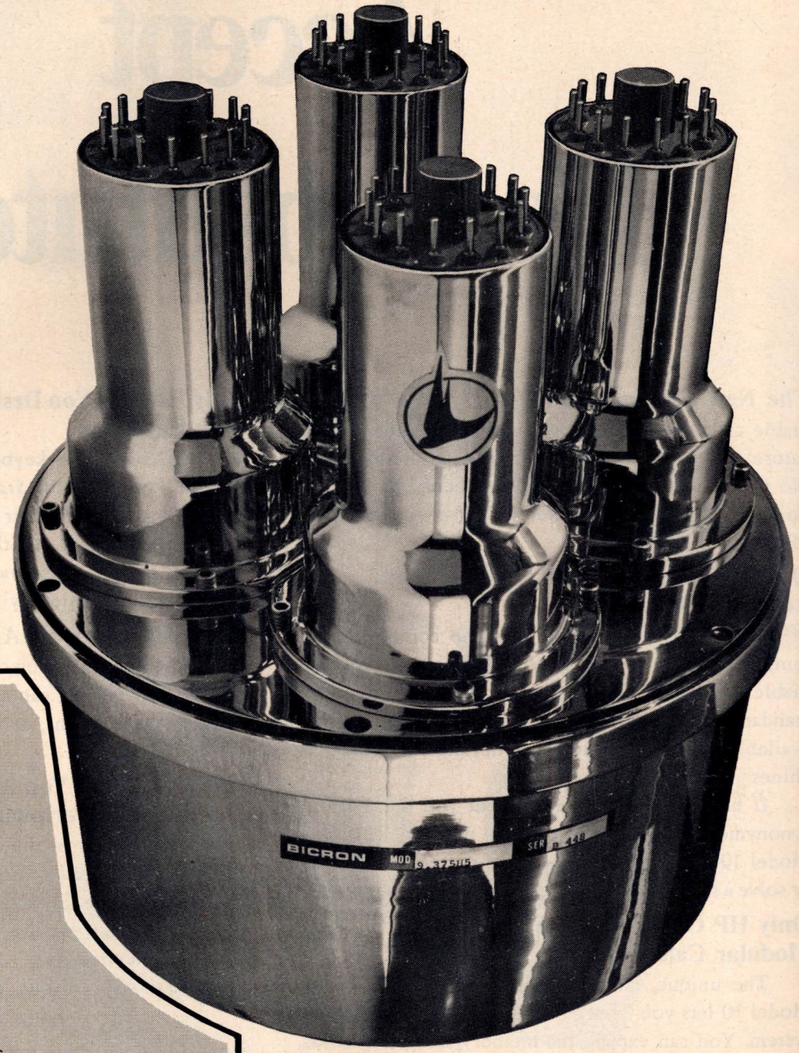

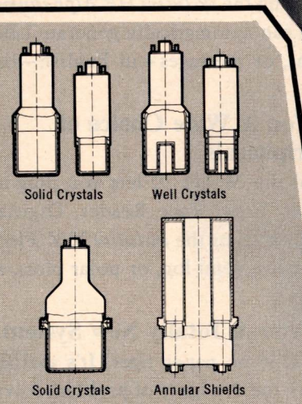

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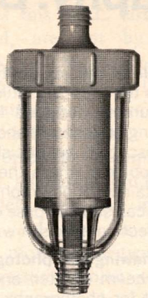

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Letters

World Modeling

The scathing review by Martin Shubik (3 Dec., p. 1014) of Jay W. Forrester's book *World Dynamics* is, unfortunately, more than the personal opinion of an angry man. It is the expression of the views of very influential groups of people, which threaten to discredit and suppress a method of forecasting which I consider as of the greatest importance and promise.

There can be no doubt that Forrester's world model is only a first approximation. It lumps together highly industrialized and developing countries. It makes quantitative assumptions about interrelations, and Shubik is of course right in his skeptical remark about their validation by "the acceptance of top decision makers." Such questions are not decided by authority. Forrester's assumptions are validated by their plausibility, and greatly reinforced by the *insensibility* of his results to the details of the assumptions.

It is somewhat hard to understand the violence of the reactions to Forrester's work, of which Shubik's review is only an example. The rational way of rejecting it would be to show that it is so critically dependent on the model, and on the policies which are fed into it, that its predictive value is nil or less than that of intuitive forecasts. To my knowledge this has never been attempted, by any of the critics. Instead they reject it out of hand, intuitively, with angry aspersions at the author and the Club of Rome.

The problem in question is nothing less than the future of mankind. Shall we treat it, as until now, "intuitively," which means, as Forrester rightly remarks, using primitive mental models, and contemptuously reject the help which the computer can give to our thinking? Surely, the rational and responsible way would be to improve the inputs by the collaboration of the widest possible circle of disciplined minds, not only econometricians but also politicians, psychologists, and creative technologists who can make guesses at new inventions which might radically alter the prospects. The costs would be negligible, not only in relation to the importance of the problem, but also in relation to what the United States spends every year on data acquisition.

DENNIS GABOR
Imperial College, London

Shubik's review fails to enlighten the reader concerning Forrester's objectives. Forrester has chosen five quantities, namely, population, natural resources, capital investment, fraction of capital investment in agriculture, and pollution, as quantities which are of most significance in the world system. Mathematically describing interrelations between these quantities, he then programs a digital computer to operate the resulting mathematical model. The trends in our world system indicated by this computer simulation are ominous indeed. Natural resource depletion turns out to be the limiting factor on growth, and population ultimately falls, to the accompaniment of a rise in pollution and a decline in the quality of life. Furthermore, none of the conventional solutions helps matters; for example, removing the natural resource constraint leads to an even more catastrophic pollution crisis and rapid die-off of population. These conclusions parallel the thinking of others both here (*1*) and abroad (*2*) attempting to view the world environmental situation holistically.

The author anticipates criticism of his work, and has ably answered the reviewer's primary objections by pointing out that governments readily concoct legislation which is presumed to correct ills in the social systems but which is in fact based merely on mental images of the real systems, images which are far less accurate than those he has constructed for computer analysis. The reviewer has wandered further onto shaky ground by attempting to liken the author's work to the analysis of RLC circuits. Forrester correctly describes the world system as a complex, nonlinear, multi-loop feedback system, and his programming reflects this. RLC circuits, on the other hand, are not by themselves feedback systems but are simply passive, essentially linear networks of electrical quantities and are of doubtful relevance to the discussion.

Forrester's dynamic model is by his own admission crude; but even crude models often give insight into a problem and serve as stepping-off points for more sophisticated models. That Forrester's model seems to be inherently unstable is a matter for thought, concern, and further research, not ridicule or head burying.

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1. "Man in the living environment," report of the Workshop on Global Ecological Problems (Institute of Ecology, Madison, Wis., 1971).
2. A. Lewis, *New York Times*, 14 January 1972, pp. 1 and 8.

. . . A substantial error in interpreting the book results from the reviewer's not taking note of the book's history as given in the preface. His remark "the Club of Rome, which sponsored this work . . . should provide some guidance" implies that the book is a consequence of the sponsored project. The preface clearly states: "On June 29, 1970, I attended a meeting of the Club of Rome in Bern, Switzerland . . . the group was invited to Cambridge . . . a meeting convened on July 20 for ten days of study, presentations, and discussion. The dynamic model of world interactions described in this book was devised in the early part of July to form a basis for discussion at the conference. It must be considered a preliminary effort. . . . As a result of the July meeting, the executive committee of the Club of Rome decided to establish a one-year research program at M.I.T. An international team under the leadership of Professor Dennis L. Meadows is going beyond the model described here to explore more deeply the underlying assumptions and the several major subsystems that form the sectors of the total world system." The content of the book led to the establishment of

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the project at M.I.T. and is not a report on the output of the project. The book was an unsponsored personal effort. The project sponsored by the Club of Rome and the Volkswagen Foundation has been for the purpose of extending the model, modifying and documenting the assumptions, and discussing the inputs as well as the consequences by working with scientific research groups in other institutions who have relevant information and opinions. The published results of the project will begin to appear soon.

JAY W. FORRESTER

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Unlike many of my colleagues who are extremely skeptical about large-scale simulation, data banks, and the organized use of politico-socioeconomic models, I believe (and am on record as believing) that an effort of the magnitude of the United States space program should be mounted to do this work. Where Forrester and I differ is that, although we may both see the limitations of econometrics and the importance of model building in areas where measures are hard to obtain, we have different views of what is feasible and useful. In my reading of his *Industrial Dynamics* and *World Dynamics* and glancing at *Urban Dynamics*, I have not seen anything to suggest that the models presented are other than extremely simplistic, given the current state of knowledge in the social sciences. I fear that if Forrester, with his drive, energy, and intelligence, were to obtain large funding for his work at the national level, he might easily be the source of a fad for producing grossly oversimplified models, which after a few years would bring about a reaction that would seriously set back progress in simulation, data bank creation, and large-scale social-scientific investigation. . . .

In reply to the specific points in Gabor's letter, I should say first that it appears to me the burden of proof of the relative worth of Forrester's work lies somewhat with its proponents. I have not seen this proof forthcoming. No evidence is given in Forrester's books that his results are insensible to the details of the assumptions. Furthermore, contrary to Gabor's assumption, such insensibility is not always a merit. Those who have worked with industrial, economic, social, or psychological simulations (Orcutt, Simon, Coleman, Abelson, Adelman, Crecine, Clarkson, to name a few) are well aware of the difficulties of obtaining a good first-approximation model. If it is too insensitive to parametric sensitivity analysis, the model is probably concentrating on the wrong variables. If it is highly sensitive, then data sufficiently accurate for the purposes at hand are probably impossible to obtain.

The application of careful dimensional analysis and the specification of good measures in the right dimensions are all difficult and critical. For instance, what is a measure of "welfare"? Even given a measure, what is its operational significance? Answers to questions such as these call for an intimate knowledge of subjects such as economics, sociology, psychology, and political science. Why are so few social scientists referred to by Forrester? Are there none whose knowledge is worth considering when building models of social, political, economic processes? In fact, there are many who have both deep substantive knowledge and the ability to use computers and who are convinced that the computer and computer models are critical for good social scientific exploration. Consider, for example, the Brookings SSRC model, Tinbergen's work on planning, Orcutt's simulation, or Klein's econometric models. Forrester in his writings does not tell us why such other workers' applications, their sensitivity analysis methods and model building, are not as good as his.

I believe that a proper scientific evaluation of the work on planning and forecasting models in the social sciences is of great importance. This, of course, should include Forrester's work. I propose to Gabor, to the Club of Rome, to the AAAS, to NSF, and others that a project be sponsored or at least a conference be held to initiate such an evaluation. It may turn out that Forrester's work is better than, as good as, or worse than that of Balderston and Hoggatt, Clarkson, Kalman Cohen, Coleman, Crecine, Cyert and March, Gordon, Klein, Leontief, Manne, Markowitz, Meyer, Naylor, or Orcutt, to name a few. An examination of Forrester's contribution to this large body of work in such a context could be of benefit to all. It might provide him with the opportunity to join with members of the growing body of social scientists working on social systems. I should be happy to supply him with a list of eminently qualified judges of work of this nature, in the fields of artificial intelligence, computer science, communications, eco-

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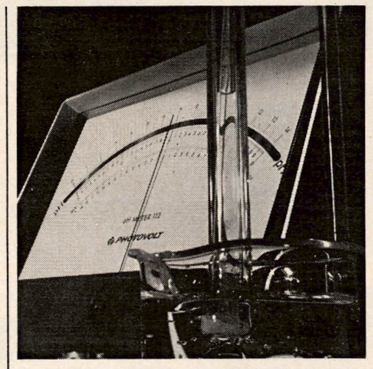

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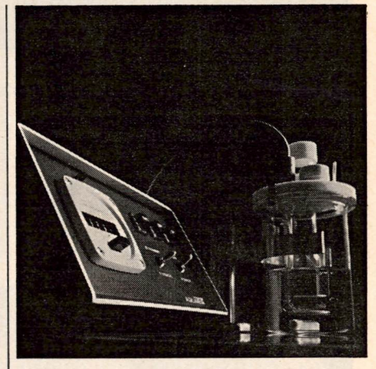

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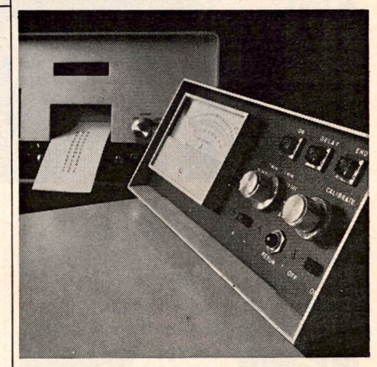

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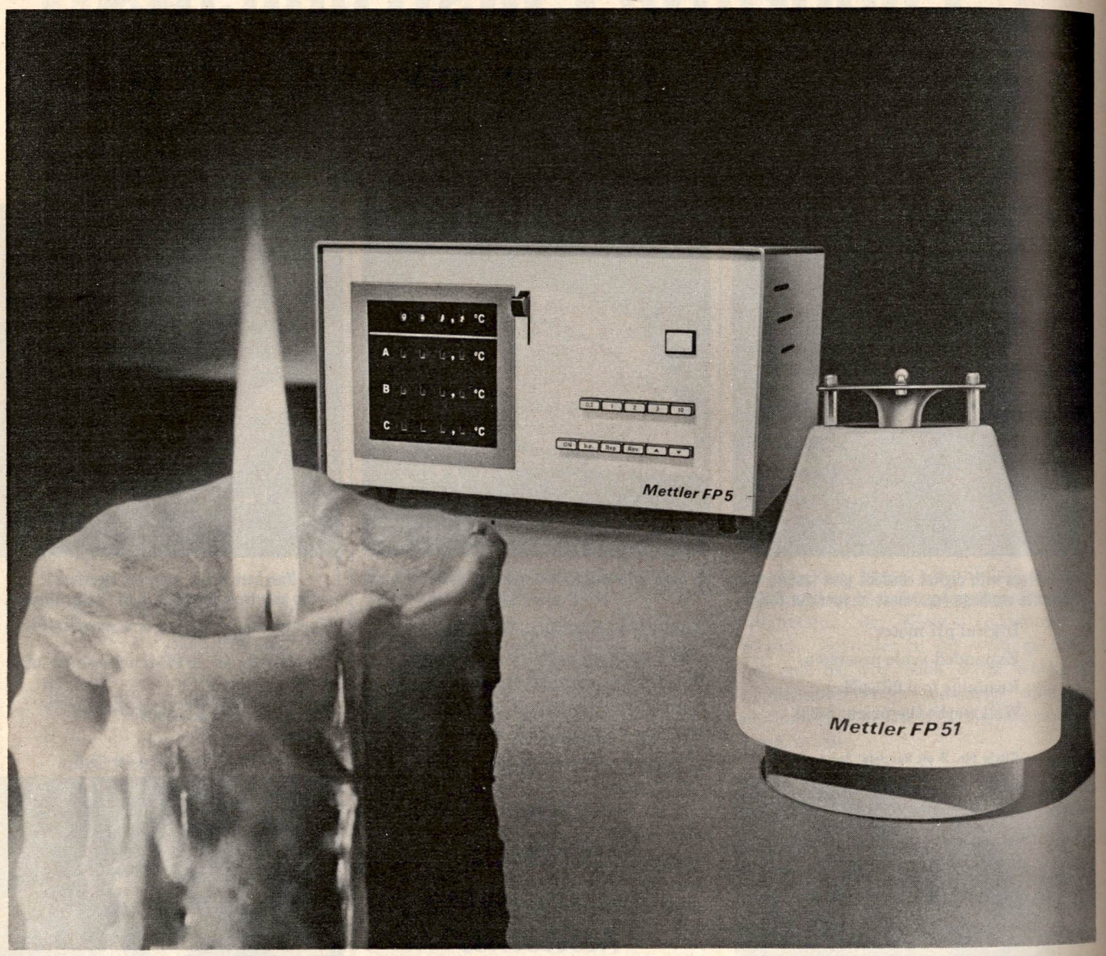

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Test Bias

The letter (24 Dec. 1971, p. 1278) by Kenneth Clark and Lawrence Plotkin was meant to correct what they describe as "three egregious misstatements" in Stanley's article "Predicting college success of the educationally disadvantaged" (19 Feb. 1971, p. 640) where he discussed, among many other studies, one by Cleary (*1*). Clark and Plotkin took out of context a single sentence in the 7½-page article: "Cleary tried to replicate the findings of Clark and Plotkin [*2*] with a better controlled design, but failed." This conclusion referred to Stanley's prior quotation from the Clark and Plotkin study: ". . . Clark and Plotkin . . . had reported results of a study based on 'alumni' classes of the National Scholarship Service and Fund for Negro Students in which they concluded that:

> . . . scholastic aptitude test scores are not clearly associated with college grades. It is suggested that college admissions officers weigh test scores less, since they do not predict the college success of Negro students in the same way they do for whites. This study indicates that motivational factors are probably more important than test scores in the demonstrated superiority of Negro students in completing college."

Stanley was not questioning their conclusion that an able, highly motivated group of black students persisted well to graduation in a variety of interracial colleges during the 1950's. (For example, see note 19 in Stanley's article.) He did, however, cite much evidence—including Cleary's study—that Scholastic Aptitude Test scores and high school records tend to predict the college grades of blacks at least as well as they do those of nonblacks. In their letter Clark and Plotkin disregard this other evidence and thereby imply that Stanley's whole case rests on the Cleary study alone, which they seem to perceive as part of an Educational Testing Service plot against them ("Accustomed as we have become for our study to be the launching pad for ETS papers. . ."). Although one need not defend the professional integrity of researchers at ETS (*3*), we note that neither Stanley's article nor most of the reports he cites were done at ETS. Some of the strongest evidence came from investigations by black non-ETS researchers such as S. O. Roberts, Joseph P. McKelpin, and Charles Leo Thomas and from studies in Illinois, Maryland, Georgia, and the Seven Sisters colleges. Even a glance at the bibliography in the Stanley article would indicate the broad data on which he based his conclusions. (Indeed, only three lines of his paper were devoted to the Cleary article.)

Since Clark and Plotkin have chosen to criticize the Cleary article, let us consider the points they make. Clark and Plotkin say that their data were better than Cleary's because they "had data on over 1200 Negro subjects (with questionnaire response from over 500) drawn from all sections of the country and distributed in hundreds of diverse colleges." The quality of data is, of course, always relative to the purpose they are to serve. For the conclusion of Clark and Plotkin that an admissions officer (who necessarily works within a single institution) should weigh test scores less, distribution of the sample among "hundreds of diverse colleges" is a disadvantage rather than an advantage. For the admissions officer, Cleary's within-college analysis is clearly more relevant. Since Cleary was able to analyze data in only three colleges, she limited her conclusions: "The schools used in this study do not represent the full spectrum of colleges in the United States, so general conclusions cannot be reached." But there are many studies other than Cleary's in which the within-college analysis has been performed, and most of these were reviewed in the Stanley article. With each new analysis, the Clark and Plotkin conclusion becomes less credible.

In their criticism of the Cleary article, Clark and Plotkin persist in their emphasis of correlation coefficients to the exclusion of regression lines. It is well known that the size of a correlation coefficient is a function of the variability of the group: when the range of scores is restricted, the correlations are attenuated. For this reason and others, the comparison of regression lines is a more appropriate analysis. Clark and Plotkin computed no correlation coefficients or regression equations, nor did they even work within colleges. Instead, they pooled college grades from 187 different colleges and

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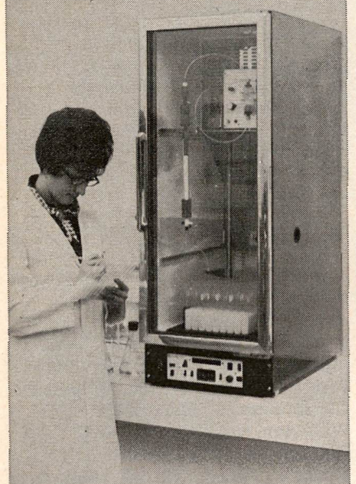

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universities (*2*, pp. 58–59), thereby treating grades at highly selective institutions as equivalent to grades at unselective ones. (We recognize that they had no choice in this matter; at the time of their study, institutions of higher education were so severely segregated that a useful within-college analysis in integrated colleges was impossible.)

Rather than focus on correlations, Cleary proposed a definition of test bias that was to be examined in her study (*1*, p. 115):

> A test is biased for members of a subgroup of the population if, in the prediction of criterion for which the test was designed, consistent nonzero errors of prediction are made for members of the subgroup. In other words, the test is biased if the criterion score predicted from the common regression line is consistently too high or low for members of the subgroup. With this definition of bias, there may be a connotation of "unfair," particularly if the use of the test produces a prediction that is too low. If the test is used for selection, members of a subgroup may be rejected when they were capable of adequate performance.

She was able to conclude that, in these colleges, the SAT was as appropriate for the prediction of college grades of blacks as of whites (*1*, p. 123):

> In the two eastern schools, there were not significant differences in the regression lines for Negro and white students. In the one college in the southwest, the regression lines for Negro and white students were significantly different: the Negro students' scores were over-predicted by the use of the white or common regression lines. When high school grades or rank-in-class are used in addition to the SAT as predictors, the degree of positive bias for the Negro students increases.

In their letter Clark and Plotkin state that one has to examine Cleary's tables to find the differences in correlations for blacks and whites, because she fails to mention them in her text. In fact, in both the earlier *Research Bulletin* (*4*) which they cite and the journal article (*1*) cited by Stanley, three paragraphs are devoted to correlation coefficients; the differences are pointed out and explanations are proposed.

Clark and Plotkin are correct that there may have been some misidentification of race in the Cleary study: in only one school were records of race available from the college; in the other two colleges identification was made from photographs, with corroboration provided from an NAACP list in one of the colleges. Gross errors in classification would be required, however, to change the results markedly.

Testing and Fair Employment (*5*) is cited by Clark and Plotkin to indicate that differential racial validity is a problem in industrial settings. This is really not relevant to the question of the SAT in educational prediction. Even so, several important points may be noted: (i) the book routinely examines correlation coefficients, rather than regression lines; (ii) all but one of the studies has very small samples of Negroes, usually about 31, and yet large numbers of correlation coefficients are computed and compared; (iii) in the only study with a reasonably large sample (98 Negro and 437 white), differential validities were not found; and (iv) in the one educational study that they say contradicts Cleary's results, the Negro and white students were in different schools, although they took the same criterion tests (State Examinations in Nursing).

In two recently published studies of educational predictions, Temp (*6*) and Davis and Temp (*7*) argue strongly for validity studies in all institutions that are using the SAT (or any other admission tests or predictors) for the selection of students. We agree with this recommendation. The College Board provides, through the Educational Testing Service, free validity studies to any institution that uses the SAT in its admissions process. Users of the SAT are encouraged to study the separate regression lines for Negro and white students (as well as other groups such as males and females) so that they can make reasoned judgments about the utility of the test for groups of students in their institution.

T. ANNE CLEARY
College Entrance Examination Board, 888 Seventh Avenue, New York 10019
JULIAN C. STANLEY
Department of Psychology, Johns Hopkins University, Baltimore, Maryland 21218

References and Notes

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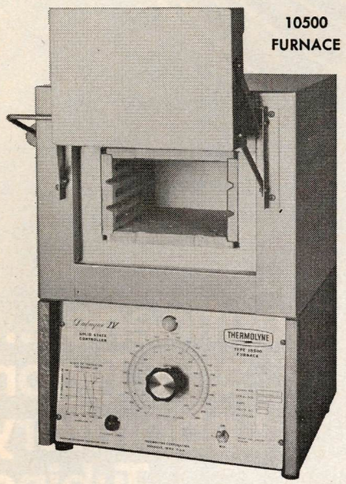

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Psychology and Health Care

John Walsh (News and Comment, 3 Dec. 1971, p. 1003) reports on "Health manpower training: Funding levels at issue" and describes certain inherent problems of fiscal, political, and manpower balance. Both Walsh's comment and the legislation that was enacted omit realistic consideration of a major health profession—psychology.

In terms of hospital beds, patients affected, community services provided, professionals involved, or funds expended—to say nothing of social cost—mental disorders constitute a very major and substantial health problem. Yet the current national-level proposals for health insurance and the broad range of existing prepaid health coverage largely exclude or seriously limit coverage for mental disorder. These proposals and existing coverage commonly exclude the services of psychologists or fail to recognize psychologists as the independent health practitioners that they are—licensed in 44 states and the District of Columbia and represented by a national organization of over 33,000 members, the American Psychological Association.

If there is any doubt that psychology has major substantive relevance and capacity to deliver in this arena, or that mental disorder is not a major health problem, I would recommend a review of the ten reports (published as separate texts by Basic Books, New York) of the Joint Commission on Mental Illness and Health appointed by President Kennedy. Six of these texts were authored, and one coauthored, by psychologists, perhaps evidence both of the preeminent scope of knowledge which my profession has to contribute to this field and its documented willingness to participate in the resolution of health problems at the national level.

HERBERT DÖRKEN
Department of Mental Hygiene,
State of California, Human Relations Agency, 744 P Street,
Sacramento 95814

Research Management

In the editorial (1 Oct., p. 11) that was excerpted from the 1945–1946 Carnegie Institution yearbook (*1*), Vannevar Bush seems to imply that fundamental research cannot be managed, but only supported, with the management of a program left to the scientist conducting the research. Quite the contrary! Experience in industry has repeatedly shown that the scientist conducting the research is frequently the poorest choice as manager due to his lack of objectivity, or removal from personal involvement. It has been far more successful for the manager to be a separate person from the researcher, although also a scientist.

The "managed" approach has also more successfully kept the final objective in clear focus. The alternative course, as advocated by Bush, frequently results in a diffuse approach, which either never comes to grips with the central problem, or takes a considerably longer time to do so.

The managed approach is not without its disadvantages or risks. But even Bush's "eminent" scientists must make judgments and take the chance of making a wrong choice. The central issue is to make sure that the managers or management groups are properly staffed. If the scientists are anywhere as eminent as Bush contends, they should have no difficulty convincing their managers of the wisdom of their choices. None of us likes to be called to account for our work and forced to justify the direction we have chosen. But in the balance, this is preferable in the case of any national commitments we might choose to make, now or in the future.

F. LOUIS FLOYD
Post Office Box 197
Spring House, Pennsylvania 19477

Reference

1. Report of the President, *Carnegie Inst. Washington Yearb.* **45**, 1–13 (1946).

The College Professor

Because the AAAS has recently made efforts to reform its governance, I decided to read the list (18 Feb., p. 804) of AAAS officers, committees, and representatives. An intriguing pattern began to emerge; of the scores of academic men and women listed, only two are affiliated with an undergraduate college (if we regard Dartmouth, the City College of New York, and Queens College as entities greater in scope and size than a "college"). Of these two, Rhoda Dorsey, who is on the Committee on Minorities in Science, is apparently a representative not only of the majority sex in America but also of a significant minority in academia, the *college* professor. The other, Donald Aitkin, is on the Youth Council.

Why does the AAAS have active participation from all components of its membership save from those colleges that do not grant doctorates? These institutions represent an important segment of our educational system, and prepare many of our future teachers, doctors, and (hopefully) scientifically aware citizens. I hope that the AAAS officers will recognize that science is not the province only of the university, the corporation, and the government.

CARL STEPHEN PIKE
Department of Biology,
Franklin and Marshall College,
Lancaster, Pennsylvania 17604

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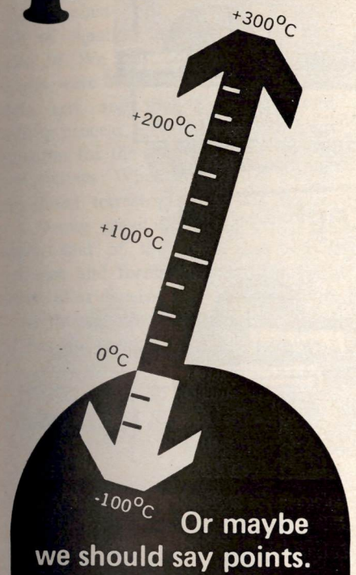

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Machine Translation

H. Wallace Sinaiko comes to substantially the same conclusion in his letter (17 Dec., p. 1182), "Translation by computer," as that of a National Academy of Sciences–National Research Council committee in 1966. The members of that committee (chairman John R. Pierce, John B. Carroll, Eric P. Hamp, David G. Hays, Charles F. Hockett, Anthony G. Oettinger, Alan Perlis) are gratified at this confirmation.

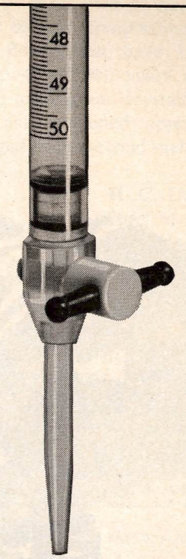
JOHN R. PIERCE
Department of Electrical Engineering, California Institute of Technology, Pasadena 91109

Reference

1. *Language and Machines, Computers in Translation and Linguistics*, report of the Automatic Language Processing Advisory Committee (Publ. No. 1416, National Research Council, Washington, D.C., 1966).

Lunar Basalts

We agree with most of Allen L. Hammond's review (Research News, 25 Feb., p. 868) of the history and structure of the moon. However, there is one important point that should be clarified. He says, "Within this period, two major phases of thermal evolution have been identified: (i) widespread melting that apparently occurred about the time of the moon's formation; and (ii) partial melting beginning as early as 4.1 billion years ago to form basalts enriched in potassium, rare earth elements, and phosphorus (KREEP basalts), and somewhat later, flooding of preexisting basins with lava to form the lunar maria between 3.1 and 3.7 billion years ago." He makes other remarks that are not clear about the times at which the basalts were formed.



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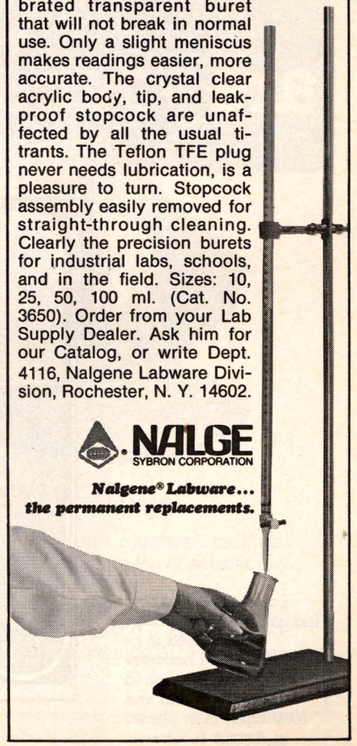

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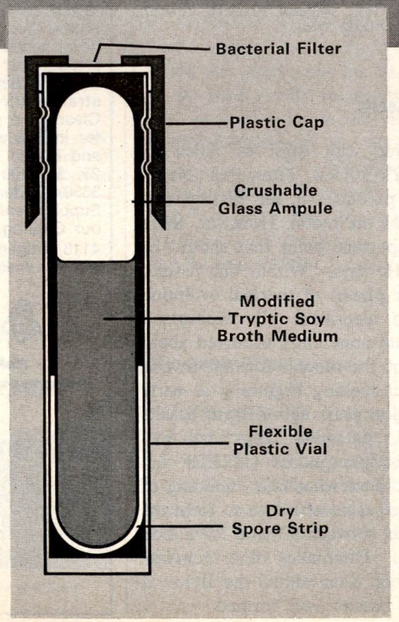

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We conclude that the maria basalts acquired their gross composition 4.5 to 4.7 billion years ago, and that this composition was only slightly modified in the second melting about 3.1 to 4.0 billion years ago. This point was discussed at the Second Lunar Science Conference by Urey *et al.* (*1*), and it has been clearly established by Wasserburg *et al.* (*2*) with an isochrone plot of ^{87}Rb against ^{87}Sr in the average soils of Apollos 11, 12, 14, 15, and Luna 16. We must conclude that these basalts were formed about 4.6 billion years ago, and that a closed-system melting process occurred later. Our explanation for the closed-system melting is as follows: When melting (of undifferentiated terrestrial material) occurs in a strong gravitational field, for example, that of the earth, the liquid separates and forms an extensive pool which, after considerable accumulation, bursts through to the surface. This liquid has the composition of basalt, and the unmelted material below has another composition. The rubidium-strontium composition differs in the two fractions. Because the moon has a weak gravitational field, liquid and solid separate less completely or not at all; when a previously formed basalt melts, solid and liquid flow out together, and the mixture has the same composition as that of the original pack of basaltic rock. The relative distribution of rubidium and strontium in different minerals was changed in the remelting process, although the overall ratio of Rb to Sr was not changed; hence, two isochrones are secured, one when the data from individual crystals of mare basalts are plotted, and the second when the gross compositions of the different mare basalts are plotted. This is the observation of Wasserburg *et al.* (*1*). Our arguments are somewhat different and involve the uranium and thorium-lead dates as well, but we arrive at the same conclusion. We also give a suggestion about the thermal history of the moon, but what we wish to emphasize is that the basaltic composition of the lunar-ash flows must have been acquired 4.5 to 4.7 billion years ago, in the primitive melting and crystallization process, and remained approximately unchanged in the second melting process.

H. C. UREY
KURT MARTI

Department of Chemistry, University of California, San Diego, La Jolla 92037

References and Notes

1. H. C. Urey, K. Marti, J. W. Hawkins, M. K. Liu, *Proceedings of the Second Lunar Science Conference* (M.I.T. Press, Cambridge, Mass., 1971), vol. 2, pp. 987–998.
2. G. J. Wasserburg, G. Turner, F. Tera, F. A. Podosek, D. A. Papanastassiou, J. C. Huneke, *Lunar Science-III, Lunar Science Institute, Contribution No. 88* (Lunar Science Institute, Houston, 1972), p. 788; D. A. Papanastassiou and G. J. Wasserburg, *Earth Planet. Sci. Lett.* **13**, 368 (1972).

3. We acknowledge support from NASA contract NGR 05-009-150.

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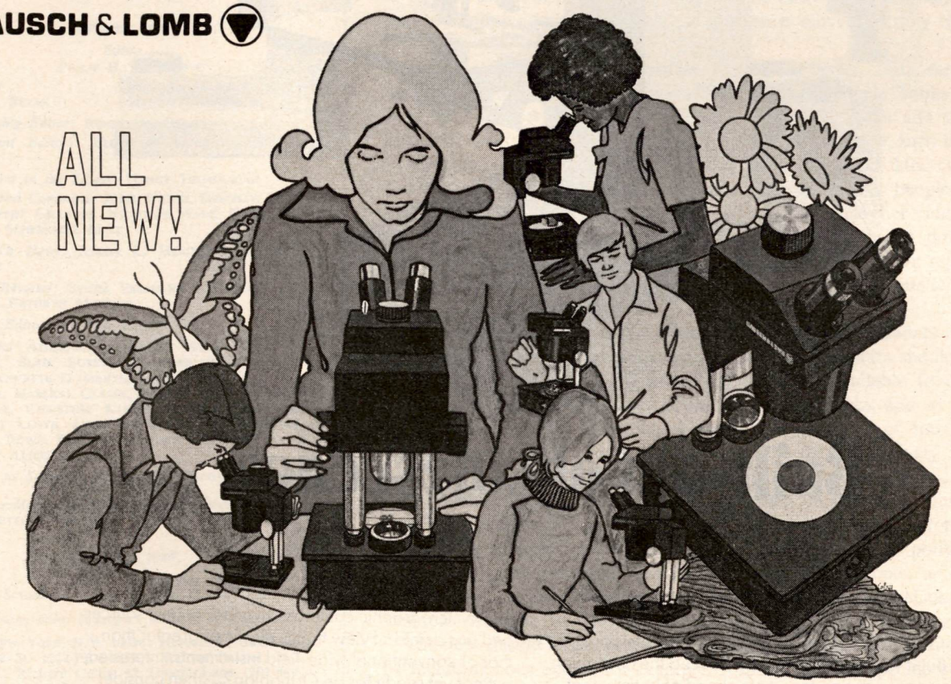

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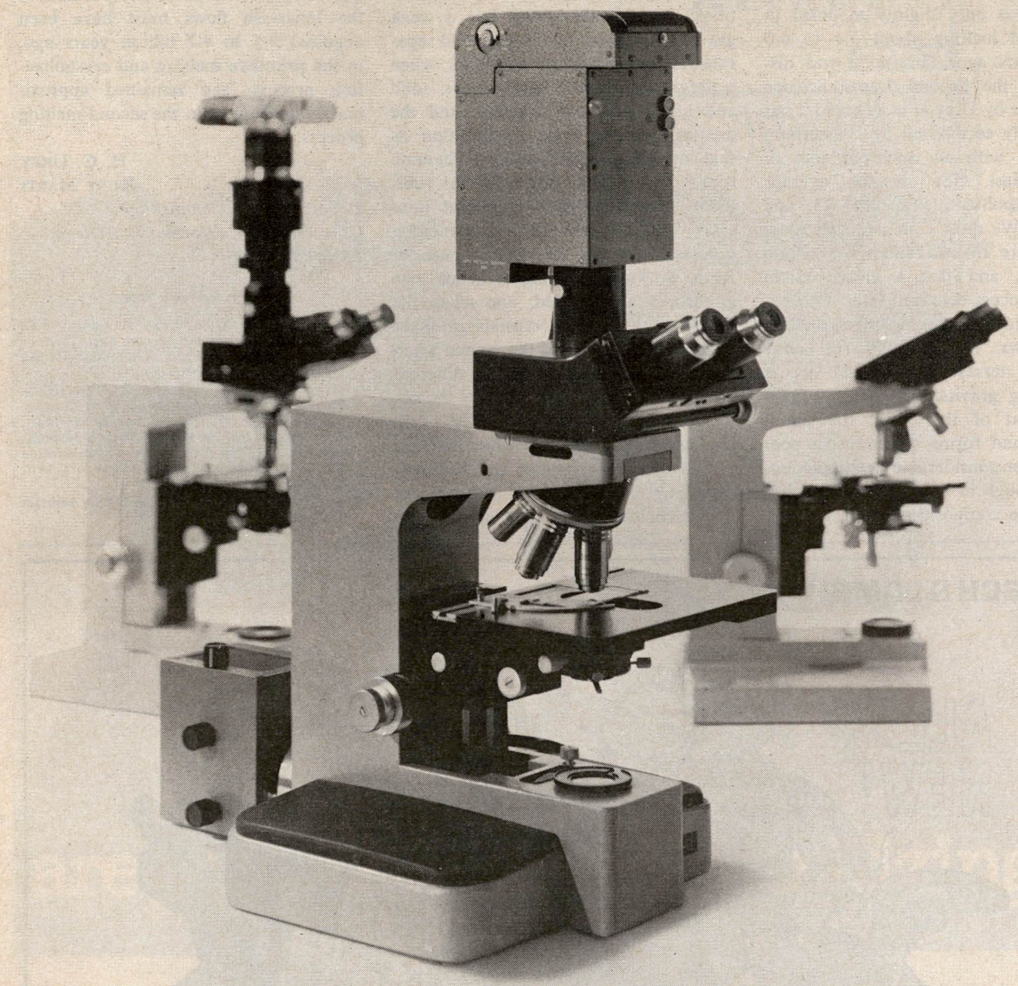

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Who Should Ultimately Own the Data?

I have just been informed that, in the next meeting of a National Institute of Mental Health review committee on which I serve, 31 research proposals will be assessed. If the committee has a good weekend, we shall allot $1 million or more of public funds. Scores of other such committees, within federal, state, and city agencies, will award much larger amounts. A good part of the tax monies involved will end up paying for the collection or production of data. The question is what happens to this data, and what ought to happen to it, once the original researchers lose interest.

Often the data rots, disintegrates, or is otherwise lost or inaccessible. Decks, tapes, and records are stored in attics or basements at home or on the campus. In some cases, the bewildered widow of the deceased researcher asks his colleagues to "clear away the junk"; in others, it is thrown away with yellowing blue books, early drafts of manuscripts, and books that came apart when the professors moved, as they frequently do.

Data stored on the campus often fares little better. Data decks warp and get moldy; tapes may erase. Most important, code books are not kept with the material or are not updated as the decks and tapes are changed, making the data unusable. Records, unprotected, turn into dust.

More than the original investment is lost. Often the data cannot be duplicated (for example, public opinion polls of views people held in the 1940's). Continuity is undermined, since one researcher cannot build on the efforts of earlier researchers. Also, as the published portions of the studies often do not contain sufficient data to allow for replication, the mutual check by colleagues on the validity and quality of the research findings suffers.

I therefore suggest that government agencies and foundations which finance mass collection or preparation of quantitative data should require that the data generated will eventually be made available to other researchers, by depositing a copy of the data (tape, decks, and so on) in a data bank or library. It would be up to the recipients of the funds to decide when they no longer need to keep the data exclusively for their use (that is, when they have published all they hope to get out of it or their interest has moved elsewhere) and which data bank or library will benefit from their copies. It will also be up to each researcher to decide if his data is sensitive (for example, highly personal or political), in which case some omissions may be called for (for example, no personal identification of the subjects should be provided in medical data about venereal disease).

The data should be deposited in a way that renders it usable by others—by including code books, for example. Appropriate and specific budgetary provisions for preparing such copies (which are not costly) should be made on all grants and contracts.

If such measures are taken, perhaps initially only for those studies in which the investment in the data is $100,000 or higher, it must be expected that the public's investment in research will yield fruit that can be shared more widely, enjoyed for longer periods, and, not least, be of better quality.—AMITAI ETZIONI, *professor of sociology, Columbia University, Director, Center for Policy Research, 475 Riverside Drive, New York 10027*

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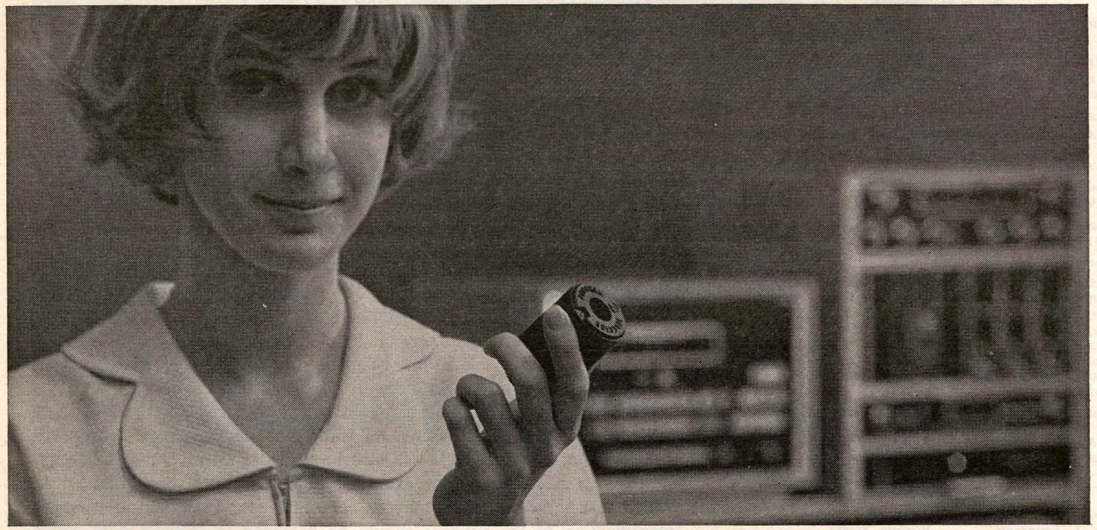

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14 April 1972, Volume 176, Number 4031 **SCIENCE**

The Human Nature of Human Nature

Theories that human behavior is based on instincts violate the findings of developmental biopsychology.

Leon Eisenberg

Understanding the nature of man and his works has become a precondition for the survival of our species, as well as for the enhancement of the flowering of human individuality. The search for that understanding is the central purpose of the university and the source of its relevance to society. After a period of public worship that verged on idolatry, universities have become the target of sustained and bitter attack. Yesterday's idolatry may have been a worship of false gods: credentials to an affluent life, technological virtuosity with little concern for its ends, and a meritocracy that excluded ethnic and linguistic minorities. But today's exorcism is aimed at false devils: the freedom to explore unpopular ideas, the transmission of our cultural heritage, and the support of fundamental research. The young excoriate universities for their corruption by the Establishment, the Establishment for their receptivity to the new, and governments for their failure to guarantee docile citizens.

The criticism, if indiscriminate and shrill, is not without substance; it must be heeded if the universities are to exercise the accretions of age. Like others, those connected with the university find it easiest to do what they have done before. Yet, if there is a single leitmotiv of our time, it is a constantly accelerating rate of change. With each decade, scientific findings translated into technology radically reshape the way we live. Technical capacity has been the ruling imperative, with no reckoning of cost, either ecological or personal. If it could be done, it has been done. Foresight has lagged far behind craftsmanship. At long last we are beginning to ask, not *can* it be done, but *should* it be done? The challenge is to our ability to anticipate the second- and third-order consequences of interventions in the ecosystem before the event, not merely to rue them afterward. The power of our technology so foreshortens the time between its application and the possibility of its correction that we must learn to think through before we act out (*1*).

If we were to understand each other even half as well as we comprehend the energy of the stars, we might yet spare ourselves the horrors we face from traducing those energies into weapons that endanger all life. If psychiatry cannot yet provide a firm basis for that understanding, it may nonetheless be of service if it dispels the myths and the pseudoknowledge that obscure the search for truth.

The author is professor of psychiatry at Harvard Medical School and chief of psychiatry at the Massachusetts General Hospital, Boston 02114. This article is based on an address presented at Faculty of Medicine Day, McGill University Sesquicentennial Celebration, Montreal, Canada, 1 October 1971.

Self-Fulfilling Prophecies

The title of this article implies its conclusion: that there is to human nature a nature that is other than naked ape, actuated by territorial imperatives and impelled by aggressive instincts. Such a conclusion must seem outrageously optimistic in an era in which Americans "waste" Vietnamese, in which West Pakistani massacre their countrymen to the East—but there is no need to retell the litany of violence. How, in the teeth of this "evidence," can we disbelieve Morris, Ardrey, or Lorenz (*2*)? How can we challenge Freud, his illusions of civilization shattered by the barbarities of World War I when he wrote (*3*): "The very emphasis of the Commandment: Thou shalt not kill, makes it certain that we are descended from an endlessly long chain of generations of murderers whose love of murder was in their blood as it is perhaps also in our own . . ."? Or again (*4*): "The tendency to aggression is an innate, independent, instinctual disposition in man . . ."? How, indeed?

This is no mere academic exercise, of concern only to students of behavior. The planets will move as they always have, whether we adopt a geocentric or a heliocentric view of the heavens. It is only the equations we generate to account for those motions that will be more or less complex; the motions of the planets are sublimely indifferent to our earthbound astronomy. But the behavior of men is not independent of the theories of human behavior that men adopt. One example may serve to explicate this thesis.

So long as the "nature" of insanity was thought to be violent, and so long as the insane were chained, beaten, and locked in cells, madmen raged and fumed. With the introduction of the "moral treatment" of the insane at the beginning of the 19th century, violence in mental asylums markedly abated (*5*). A century later, the "nature" of insanity was perceived as social incompetence; the sick were "protected" from stress, and the institution assumed

responsibility for all decision-making. Misguided benevolence stripped the patient of adult status and generated automaton-like compliance; the result was the chronicity of the back wards of our state hospitals. A generation ago, the concept of the therapeutic environment, with its rediscovery of self-government and personal responsibility as the bases for attaining competence, began to reverse the cycle of self-perpetuating hospitalization. This led to a decline in what had been a steadily rising population in U.S. mental hospitals, a decline that began before the era of psychotropic drugs (*6*). Do not mistake me. Psychosis is no mere social convention; it has a psychobiological existence independent of systems of belief. But its manifestations and its course are profoundly influenced by the social field in which the patient and his caretakers operate. Belief systems act no less profoundly on the remainder of mankind. The doctor's very presence relieves pain. Teachers' expectations govern pupils' performance. The citizens' confidence in the benevolence of the social order maintains its stability.

What we believe of man affects the behavior of men, for it determines what each expects of the other. Theories of education, of political science, of economics, and the very policies of governments are based on implicit concepts of the nature of man. Is he educable? Is he actuated only by self-interest? Is he a creature of such dark lusts that only submission to sovereign authority can save him from himself?

What we choose to believe about the nature of man has social consequences. Those consequences should be weighed in assessing the belief we choose to hold, even provisionally, given the lack of compelling proof for any of the currently fashionable theories. In insisting on an assessment of potential outputs in addition to a critique of inputs, I do *not* suggest that we ignore scientific evidence when it does not suit our fond wishes. Any hope of building a better world must begin with a tough-minded appraisal of the facts that are to be had. The thrust of my argument is that there is no solid foundation to the theoretical extrapolation of the instinctivists, the ethologists, the behaviorists, *or* the psychoanalysts, despite the special pleading that often is so seductive to those eager for a "real science" of behavior. Further to the point, belief helps shape actuality because of the self-fulfilling character of social prophecy. To believe that man's aggressiveness or territoriality is in the nature of the beast is to mistake some men for all men, contemporary society for all possible societies, and, by a remarkable transformation, to justify what is as what needs must be; social repression becomes a response to, rather than a cause of, human violence. Pessimism about man serves to maintain the status quo. It is a luxury for the affluent, a sop to the guilt of the politically inactive, a comfort to those who continue to enjoy the amenities of privilege. Pessimism is too costly for the disenfranchised; they give way to it at the price of their salvation. No less clearly, the false "optimism" of the unsubstantiated claims made for behavioral engineering, claims that ignore biological variation and individual creativity, foreclose man's humanity.

What is known about the power of the social-psychological determinants of human behavior compels the conclusion that the set of axioms for a theory of human nature must include a Kantian categorical imperative: men and women must believe that mankind can become fully human in order for our species to attain its humanity. Restated, a soberly optimistic view of man's potential (based on recognition of mankind's attainments, but tempered by knowledge of its frailties) is a precondition for social action to make actual that which is possible.

Innate Schemata and Racial Purity

Some readers may object to "politicizing" what should be a "scientific" discussion. My contention is that it is necessary to make overt what is latent in treatises on the "innate" nature of man. Consider, for example, Lorenz. Surely, those who have been charmed by his film of himself leading, like a mother goose, a brood of greylag geese about the farmyard will recoil from identifying his works as political. What is political about inborn schemata, innate releasing mechanisms, species-specific mating patterns, and the like? A great deal, as his own writings make clear, when such concepts, of dubious applicability to animal behavior itself (*7*), are transposed directly to man without attending to species differences and to phyletic levels. Lorenz found it possible to write, in 1940, that the effects of civilization on human beings parallel those of domestication in animals (*8*). In domesticated animals, he argued, degenerative mutations result in the loss of species-specific releaser mechanisms responding to innate schemata that govern mating patterns and that serve in nature to maintain the purity of the stock. Similar phenomena are said to be an inevitable by-product of civilization unless the state is vigilant (*8*, pp. 56–75).

> The only resistance which mankind of healthy stock can offer . . . against being penetrated by symptoms of degeneracy is based on the existence of certain innate schemata. . . . Our species-specific sensitivity to the beauty and ugliness of members of our species is intimately connected with the symptoms of degeneration, caused by domestication, which threaten our race. . . . Usually, a man of high value is disgusted with special intensity by slight symptoms of degeneracy in men of the other race. . . . In certain instances, however, we find not only a lack of this selectivity . . . but even a reversal to being attracted by symptoms of degeneracy. . . . Decadent art provides many examples of such a change of signs. . . . The immensely high reproduction rate in the moral imbecile has long been established. . . . This phenomenon leads everywhere . . . to the fact that socially inferior human material is enabled . . . to penetrate and finally to annihilate the healthy nation. The selection for toughness, heroism, social utility . . . must be accomplished by some human institution if mankind, in default of selective factors, is not to be ruined by domestication-induced degeneracy. *The racial idea as the basis of our state has already accomplished much in this respect.* The most effective race-preserving measure is . . . the greatest support of the natural defenses. . . . We must—and should—rely on the healthy feelings of our Best and charge them with the selection which will determine the prosperity or the decay of our people . . . [italics added].

Thus, it would appear, science warrants society's erecting social prohibitions in order to replace the degenerated innate schemata for racial purity. Lorenz's "scientific" logic justified Nazi legal restrictions against intermarriage with non-Aryans. The wild extrapolations from domestication to civilization, from ritualized animal courtship patterns to human behavior, from species to races, are so gross and unscientific, the conclusions so redolent of concentration camps, that further commentary should be superfluous. Perhaps it is impolite to recall in 1972 what was written in 1940, but I, at least, find 1940 difficult to forget; indeed, I believe it should not be forgotten, lest we find ourselves in Orwell's *1984* for the very best of "scientific" reasons.

My position should not be misconstrued as condemning the study of comparative psychology or the search for biological determinants of human behavior as though such efforts were inherently fascist. What I do inveigh against is the formulation of pseudoscientific support for a priori social ideologies that are projected onto, not "found" in, nature. Such pseudoscience ignores species differences and phyletic levels and misrepresents analogy as homology. For example, attack behavior can be observed in organisms as varied as insect, bird, carnivore, ape, and man. In the first, it may be triggered by trace chemicals; in the second, by territorial defense, but only during the breeding season; in the third, by prey, but only if the appropriate internal state of arousal is present; in the fourth, by the appearance of a predator, if escape routes are unavailable and if the troop is threatened; and in man, by a mere verbal slur, if the social context and prior individual experience indicate attack as the socially appropriate response. The mere observation in divergent species of similar behavioral outcomes that fit the generic label "attack" justifies no conclusion about an underlying aggressive instinct, without detailed study of the conditions evoking, and the mechanisms governing, the behavior of each. Such "explanations" reify a descriptive label that has been indiscriminately applied to markedly different levels of behavioral organization, as though naming were the same as explaining.

Teleology or Ontogenesis

Indeed, reports on animal behavior (*9*) fail to support the concept of an aggressive instinct as an independent motivational force analogous to hunger. That is, there is no predictable periodicity, no measurable changes in internal parameters (such as glucose concentrations in the blood), and no evidence of a "need" to attack in the absence of provocative stimuli. This is not to deny that the ease with which, and the circumstances under which, attack is elicited differs among species, nor that hormones, notably androgens, may have a profound impact on the probability of a fight rather than a flight response in higher organisms (*10*). The characteristics of the species, the genetic endowment of the individual organism, its prior experience, and the immediate stimuli interact to produce the behavioral outcome. Similar outcomes may result from quite different underlying mechanisms; meaningful comparisons become possible only when the mechanisms have been identified.

Examples could be multiplied. At the most general level, the problem stems from a telic orientation: behavior is "explained" by its outcome, rather than by an analysis of its ontogenesis. The cause is assumed to exist preformed in the organism as an "instinct" or innate pattern of behavior. The Platonic ideal is immanent in the organism. But where is it, when does it appear, and how does it come into being? Not even the most ardent instinctivist would any longer argue that the "instinct" for aggression or courtship rituals or nest building is *in* the fertilized egg. Yet it is confidently asserted that it must have been precoded and ready to go because it appears without any apparent requirement for prior learning.

Let us agree: behavior, like structure, is under genetic control. Animals of two species, reared in an identical environment, will nonetheless behave differently. The argument for innateness—in the sense of an inherited component—is compelling when the distribution of a given characteristic in an offspring generation can be predicted from knowledge of its distribution in the parent generation and the pattern of mating in that generation. However, the genetic evidence does not warrant the other sense in which innate is used—that is, developmental fixity, an imperviousness to environmental influences. Environment influences development by mechanisms that need have nothing to do with learning. For example, certain mutations in wing and eye structure of drosophila are temperature sensitive; if the eggs are maintained at 18°C, the wing or eye develops normally, despite the presence of the mutant gene. This is hardly "learning," but it is evidence that expressivity depends on the environment. It does not make the characteristic any less genetic that its phenotypic expression is modified by temperature. But, by having discovered an array of such factors, the investigator has made a start at identifying the biochemical mechanisms underlying the action of genes. The central issue in the study of development is the problem of the interactions among the programmed but modifiable unfolding of the genome, its cellular envelope, and the surround. If the nucleus of a frog's intestinal cell transplanted into an enucleated frog's egg gives rise to a normal animal (*11*), then for all of the phenotypic differences between cell types, they share, as we knew they must, the same genetic apparatus, but an apparatus whose expressivity is under cytoplasmic as well as nuclear control.

Even in closely related species, differences are more revealing than similarities in elucidating the principles that govern behavior. Consider the study of bird vocalization, which, beyond its intrinsic fascination, may yet provide important clues to the understanding of sound imitation in man (*12*). It is a graphic example of a behavioral characteristic that displays remarkable ontogenetic differences in closely related species. Song sparrows, isolated from conspecifics and foster-reared by canaries, nonetheless acquire their own song. Yet meadowlarks, similarly isolated as fledglings, acquire the song of the particular foster species: wood pewees, yellowthroats, or red-winged blackbirds (*13*). Still different is the white-crowned sparrow, which must hear the adult model of its song during a "sensitive period" of development in order to acquire it; nonetheless, if the fledgling white-crowned sparrow is simultaneously exposed to conspecifics and to two sympatric species, it "learns" only its own song. Once learned, the song persists, even if the adult is isolated. In the case of the goldfinch, the adult bird is able to learn new flight songs from other species (*14*). These few examples merely hint at the complexity of a growing field of inquiry. Precise attention to differences among species, the interrelationship of those differences with the ecology of the species, and the ultimate identification of the underlying neuromechanisms are what we will require for models that may have heuristic value in studying imitation behavior in man.

Language: A Universal Human Trait

Man's biological equipment is now, if ever, an essential topic of study. That equipment evolved over the 5 million years which elapsed between the

australopithecine homonids and *Homo sapiens*; it provided the means for survival in an environment not yet altered by artifacts. The spread of our species and the rapid multiplication of our numbers in the past five millenia attest to the adaptability of that biological equipment to circumstances that did not exist when it was elaborated. It is becoming painfully evident that the changes we have wrought in the past five decades threaten our continuing survival under conditions of an exponential rate of population growth. It now becomes necessary to ask: How adaptable is man? Is mere perpetuation of the species, without concern for the quality of life, a sufficient criterion for man, even if it has been so for nature? Man's intelligence permits him the conscious choice of goals and so differentiates him from the rest of animate existence.

How, then, to discern the nature of man? Two general approaches suggest themselves—the comparative and the developmental. In the first, we compare and contrast the characteristics of men and women in the diverse societies that people this planet in the hope of extracting common denominators that express man's "essential nature"; in the second, we study the interaction between the infant and his social and biological environment as he grows to adulthood.

One trait common to man everywhere is language; in the sense that only the human species displays it, the capacity to acquire language must be genetic. As Chomsky has pointed out (*15*), among the unique aspects of human language learning are the child's ability to infer syntactical rules from a limited set of input samples and, in consequence, his extraordinary capacity to generate grammatical sentences that he has never heard. The language he speaks is determined by the language he hears, but the capacity for language must be a consequence of the genetic programming of brain networks as these respond to maturation and experience. Languages, insofar as they have been studied, appear to share fundamental structural characteristics, a universality that argues for an as-yet-to-be-identified basis in common structures in the central nervous system. Recall the example of the white-crowned sparrow, which, though it must learn its song, is structured in such a way that its neural networks resonate only to a restricted set of external harmonic sequences. The data of linguistics suggest the possibility of a similar restriction on the form of language and the nature of grammatical structures; they imply limited variability in the neural schemata underlying language structures. Further refinement in our knowledge of these cognitive universals may yet enable us to propose models of neural mechanisms, which must then be sought experimentally.

Benzer (*16*) has brought the tools of genetic analysis to bear on behavioral mutants in drosophila. By the ingenious use of mosaics with phenotypic characteristics that permit the morphological identification of individual cells that carry or lack the mutant gene for phototaxis, he has found the source of the behavioral deviation to be structural abnormalities in the affected eye. In flies in which mosaicism is present within a single eye, histological techniques and single cell recordings can specify the deficit even more precisely. Cellular markers "provide powerful techniques for tracing the details of cell lineage during development, as well as genetic dissection of the functioning nervous system" (*17*). Even the limited complexity of the drosophila's central nervous system defies analysis by current techniques, but an important beginning has been made in relating genetically determined behavioral differences to underlying physiological mechanisms.

The Diversity of Human Culture

If language be one of the common features of human culture, even more remarkable are the diverse behaviors that cultures shape and are shaped by. What is labeled "masculine" in one culture and ascribed to the nature of maleness is regarded as "feminine" in another. Children are permitted uninhibited sexual expression and yet become monogamous adults in one culture; in another, preadult sexuality is heavily censored, whereas adult monogamy is privately violated while it is publicly proclaimed. Child care may be the responsibility of the nuclear family or of the group. The same Netsilik Eskimos who are loving and devoted parents can allow a female infant who is not "spoken for" in a prearranged marriiage to die unattended and ignored if she is not given a name and is thus, by definition, not yet human. The phenomenon of war is unknown to one-society, appears in a second only under environmental stress, but is a lethal "game" without apparent material benefit in a third. Indeed, if we were to permit ourselves the argument that the more "primitive" the society, the more true to man's original nature the behavior displayed therein, we should have to conclude, as did Sahlins (*18*), that "war increases in intensity, bloodiness and duration . . . through the evolution of culture, reaching its culmination in modern civilization." However agreeable, the argument for the pacific character of natural man, uncorrupted by the social order, is inadmissible; culture is as complete and complex in contemporary hunting and gathering tribes, despite their primitive technology, as it is in our own—man is man only in society.

What is striking in this very partial inventory is the remarkable diversity of the human behaviors evoked by various but viable cultures. If we explain the murderous raids of Brazilian Indians on the basis of an innate aggressive instinct, we shall have to invent an involved theory of repression, reaction formation, and sublimation to account for the peacefulness of the Eskimo. Would it not be far more parsimonious to begin with the assumption that men are by nature neither aggressive nor peaceful, but rather are fashioned into one or another as the result of a complex interaction between a widely, but not infinitely, modifiable set of biological givens and the shaping influences of the biological environment, the cultural envelope, and individual experience?

The very ubiquity of violence in Western society, however we explain its genesis historically, guarantees that children are surfeited with opportunities to learn violent behavior. The child sees that violence pays off; he is provided with adult models of violent behavior with whom to identify (television pales beside real life). Violence as an appropriate response to the resolution of intergroup conflict is sanctioned by national leaders. Reflect: the President of the United States intervened to prevent the immediate imprisonment of Calley, an officer convicted of mass murder in Vietnam by a jury of combat veterans. Consider: the Attorney General of the United States declined to press charges in the Kent State student murders.

What are the ethical values these actions by national leaders convey? When violence is sanctioned, it will increase. It can be expected to generalize to situations not "intended" to come within official pardon. Learning may not account completely for human aggression, but the social forces in contemporary society that encourage its development are so evident (*19*) that preoccupation with hypothesized biological factors is almost quixotic.

Emphasis on the very marked differences among cultures may obscure what has been, until recently, a conservative tradition within each. Children reared within a particular value system could expect to complete their days within that system. Values now change so rapidly that what a child is taught by his parents may no longer be functional when that child becomes an adolescent, let alone an adult. However wide the range of behaviors man can exhibit—evidenced by the comparison of one society with another—the task of developing adaptive attributes is very different when radically changed behaviors are required within an *individual's* lifetime rather than over the history of a people. The question now becomes, not how malleable is man, but how much change can a man undergo and still maintain his psychic integration?

Here we lack empirical data; there is no precedent for such rapid change. We confront the fundamental relevance of studies of child development. In a stable society, the price demanded by acculturation may or may not have been burdensome, but clearly it was bearable, or else that society would not have perpetuated itself. Studies of child development were important even then, if only to learn how to mitigate those burdens. But if we are to enable our children to cope with a world whose present shape we barely comprehend and whose future configurations we can only guess at dimly, then we are embarked on an enterprise that is the very keystone of the sciences of survival.

Man as His Own Chief Product

I will forego detailing what we already know and ignore at the peril of the next generation: that the rapidly growing brain of fetus and infant is excruciatingly dependent on the adequacy of its nutrition (*20*); surely, no further amassing of scientific facts is needed to justify international commitment to the protection of the unborn and the newly born. What has become equally evident is that the nutriment the growing brain requires is affective and cognitive as well as alimentary. The extraordinary dependence of the human young upon adult care and caring provides both an unparalleled opportunity for mental and emotional development and a period of vulnerability to profound distortion by neglect (*21*). Infants in orphanages lag markedly in development, despite normal food intake, if denied a responsive human environment. There are indeed gaps in our knowledge of this early developmental sequence: just how much stimulation is optimal, just what balance is to be struck between gratification and denial, just what is the best mix between social interaction and time to be alone? Yet the outlines are clear enough to allow no excuse for what we permit to befall defenseless children, who suffer from the contumely we visit on their parents. Each infant differs from the others: no two, except for identical twins, share a common genome, and even identical twins may differ phenotypically because of gestational inequalities. We do not understand individual variability sufficiently well to fashion optimal environments for each child, but surely this does not mitigate our failure to provide at least those general requirements shared by all children (*22*).

Ignorance, as well as lack of commitment, becomes a limiting factor when children reach the years of formal education. The shortcomings of available theories of learning constrain our ability to respond to individual differences in the way children fashion their personalities and cognitive styles (*23*). There may be much to be gained from comparative studies of animal learning—to be sure, we are primates ourselves, but primates of a very special sort. We are no less usbject to classical and operant conditioning, to trial and error learning, and the like, but only we have the capacity for superordinate modes of verbal learning, and these require much deeper study than has been devoted to them. Our challenge is no longer transmitting solutions that have been successful in the past, but helping our children to acquire attitudes and sets for problem-solving that will enable them to meet undreamed-of challenges to their capacities.

We have done least well at the task of encouraging the development of humane values based upon the recognition that we are a single species. The idea of brotherhood is not new, but what is special to our times is that brotherhood has become the precondition for survival. It may have sufficed in the past to spur a child to learn for the sheer satisfaction of his own success. If we have listened to what our students are telling us, learning for personal embellishment or for the acquisition of virtuosity no longer satisfies a generation intensely aware of injustice and impermanence. Learning must become a social enterprise, informed by concern for others (*24*).

This it can become. Man is his own chief product. The infant who discovers that he can control the movements of his own fingers transforms himself from observer into actor. The child who masters reading unlocks the treasury of the world's heritage. The adolescent who insists upon a critical reexamination of conventional wisdom is making himself into an adult. And the adult whose concerns extend beyond family and beyond nation to mankind has become fully human.

By acting on behalf of our species we become men and women. In a world in which wars rage, in which repressive governments subjugate their peoples, in which the pursuit of personal affluence ravages an environment that must be shared by all, there can be no neutrality. Members of the university community carry a heavy measure of responsibility for the privilege accorded them; that responsibility is to pledge themselves to the service of man if knowledge is to be transformed into wisdom.

The study of man takes its meaning from involvement in the struggle for human betterment. Struggle it is and will be: privilege does not surrender easily; false belief is not readily dispelled. The optimism about man's potential I urge upon you is not the self-comfort of reading history as a saga of progressive liberation which will one day be complete. It matters, and matters dearly, to Vietnamese and to Pakistani, to Americans and to Canadians, whether that day comes sooner or later; whether it comes at all is not determined by history but by the men

and the women who make history. This has been eloquently stated by the Cuban poet Padilla, who has recently been released from prison in his own country. The final lines of his poem "Important Occasions" (*25*) read:

History's going to save us—we were thinking.
Going to save us—were we dreaming?
It wasn't all just uprisings, barricades, bonfires:
in our heads it was a dress of bubbling foam, a
Rhine maiden with clear eyes, smiling, standing
at the door, hand outstretched
toward a hungry and waiting people.
But there was no one in the doorway. Nor in the house.
Instead we stumbled. They shoved us inside. We broke our teeth going in, got our jaw smashed.
We found tools and weapons and we fought, we struggled, we worked and continued
fighting. But it's true, old Marx,
that History is not enough.
Important occasions,
man makes them.
It's a real, live man who does it,
who masters it, who will fight.
History by itself does
nothing, dear friends.
It does absolutely nothing.

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Circumscribed Halos

Circumscribed halos which appear around the sun are simulated by a computer treatment of a simple model.

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Ice crystals in the atmosphere are responsible for a variety of optical phenomena in the sky. One of the most familiar of these phenomena is a circle of light around the sun, with an angular radius of 22°, as shown in Fig. 1. This halo results from sunlight deviated by about 22° by refraction through randomly oriented hexagonal ice crystals. Occasionally this 22° halo is circumscribed by another halo which is tangential to the 22° halo at the top and bottom. Unlike the circular 22° halo, the shape of the circumscribed halo varies markedly with the altitude of the sun (as can be seen in Fig. 7). In this article we analyze the source and form of this circumscribed halo.

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The Model

Ice crystals in the air commonly exist in the form of hexagonal prisms. If the length of the crystal along the axis is short as compared with its width, the crystal will have the form of a flat hexagonal plate. If the axial dimension is long, the crystal will have the shape of a hexagonal column which we refer to as a pencil crystal, after its resemblance to the shape of the common wooden pencil. These crystals, falling in still air, tend to assume the orientation which provides maximum air resistance. This means that flat plate crystals will tend to fall with their axes vertical and the pencil crystals with their axes horizontal. The details of the orientations of a group of falling ice crystals will determine the pattern of light in the sky which results from sunlight refracted by these crystals. Our approach has been to calculate the path of light rays through a distribution of ice crystals in order to find that distribution which produces the observed forms of the circumscribed halo.

The Calculation

Instead of dealing with a multitude of crystals at different locations in the sky, we have used one crystal, at one location, and have assigned to it all the desired orientations. With the invaluable aid of the computer, we have, for each crystal orientation, calculated the direction of the light ray leaving the crystal. Figure 2 shows that light passing through alternate faces of a pencil crystal is refracted as if it had passed through a 60° prism. If a light ray from the sun reaches an observer after being deviated through an angle δ by an ice crystal, the observer will have to look an angle δ away from the sun to see that light ray (Fig. 3). The angle of minimum deviation for a 60° ice prism is 22°; rays with either greater or smaller angles of incidence on the crystal face will be deviated by more than 22° in passing through the prism. The nature of this minimum in the deviation angle determines two important features of a halo: (i) the angular radius of the inside of a halo is equal to the minimum deviation angle, and (ii) the halo is brightest around its inside edge. The case of refraction by a prism treated in most optics textbooks is for a light ray that is perpendicular to the axis of the prism, and for this case the angle of minimum deviation is easily calculated. For rays that are not perpendicular to the prism axis (skew rays) the angle of minimum deviation depends on the skewness of the rays. Earlier investigators (*1*) have calculated the pattern of light in the sky that would result only from the rays with minimum deviation. Such an approach necessarily omits intensity information and the contributions of all other refracted rays.

Our calculation includes intensity information resulting from the dependence of deviation of a light ray on the orientation of the prism. In addition, we have accounted for three other factors that influence the intensity distribution. First, the intensity of the exit ray relative to the incident ray is diminished because of reflection losses at each surface. The intensity loss due to reflection depends on the angle of incidence and on the index of refraction of the crystal. Using Fresnel reflection coefficients (*2*), we have accounted for this reflection factor. The other two intensity factors that we have included are geometrical factors. For the circumscribed halo we are concerned with light that is refracted through two surfaces that make an angle of 60° with each other. The cross-sectional area of the light beam incident on the first crystal face depends on the cosine of the angle of incidence; when the projected area of the crystal face in the direction of the incident light is small, the relative intensity of the exit beam is low. These first two intensity factors have been treated exactly in our formulation. A third factor allows for the fact that only for the case in which the light passes through the crystal at minimum deviation, and normal to the crystal axis, will all the light that enters the first face pass through the second face. For all other paths some of the light transmitted by the first face will strike other faces of the crystal. We have accounted for this last geometrical factor by applying the correction appropriate to light rays that are perpendicular to the crystal axis. By using this approximate correction we have also neglected any effects due to the ends of the pencil crystals. Using these intensity-influencing factors, we calculated relative intensities for the exit rays which ranged between zero and unity. Before plotting the data we compared the relative intensity of the exit ray with a random number between zero and unity. Only if the relative intensity of the exit ray was greater than the random number did that ray contribute to the plot. According to this procedure, the effect would be, for example, that only one-tenth of the spots associated with rays having a relative intensity of 0.1 would be plotted.

The orientation of a crystal is determined by the specification of three angles. We assign sets of random values to the three angles with appropriate weighting factors to produce the desired distribution. The following approach is used to make a plot of the

Fig 1. Photograph of a 22° halo.

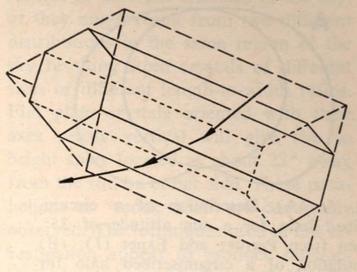


Fig. 2. Light ray passing through a hexagonal ice crystal.

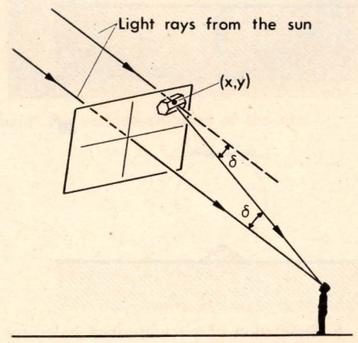


Fig. 3. An observer viewing a light ray refracted by an ice crystal.

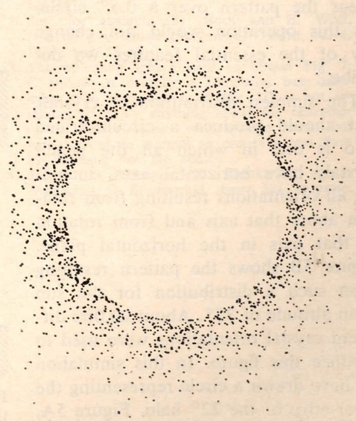


Fig. 4. Simulation of a 22° halo.

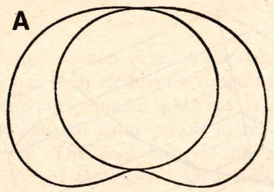
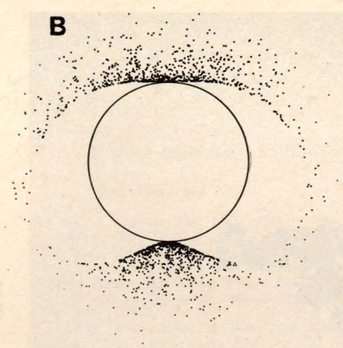


Fig. 5. (A) Description of a circumscribed halo for a sun altitude of 35°, taken from Pernter and Exner (*1*). (B) Simulation of a circumscribed halo for a sun altitude of 35°.



simulated halo: after the direction of the exit ray is determined, we calculate the coordinates of the point in a plane (normal to a line between the observer and the sun) at which the crystal can be located to give an exit ray which points toward the observer. The situation is depicted in Fig. 3. We calculate the coordinates of several thousand points for each simulation and plot them automatically. The number of points per unit area is proportional to the intensity of the light.

Results and Discussion

As a special case of our formulation, a random distribution of orientations of the ice crystals should produce a simulation of the 22° halo. The result is shown in Fig. 4, which may be compared with the photograph of an actual halo shown in Fig. 1. The simulated halo shows the intensity distribution for red light. In all of our simulations we have ignored the diameter of the sun; our results are those predicted for a point sun. To take the diameter of the sun (0.5°) into account, we could smear the pattern over a 0.5° circle, but this operation would not change any of the essential features we describe.

The simplest distribution of crystals that should produce a circumscribed halo is one in which all the pencil crystals have horizontal axes, including all orientations resulting from rotation about that axis and from rotation of that axis in the horizontal plane. Figure 5B shows the pattern resulting from such a distribution for the sun at an altitude of 35°. About 20,000 different crystal orientations were used to produce this figure. In this simulation we have drawn a circle representing the inner edge of the 22° halo. Figure 5A, taken from Pernter and Exner (*1*), shows their locus of rays with minimum deviation for horizontal crystals for this same sun altitude. The locus of minimum deviation matches the inner boundary of our intensity distribution.

It is clear, however, that the intensity information contained in the dot diagrams adds a great deal of predictive value to the simulation.

Figure 6 shows the resulting intensity distribution for pencil crystals with horizontal axes for several different values of the sun altitude. A horizon has been added to each of the figures along with a circle of 22° radius. For sun altitudes less than about 30°, there is no light at the sides of the halo and the halo separates into two segments. These are generally referred to as the upper and lower tangential arcs. For sun altitudes between 30° and about 40°, the circumscribed halo extends completely around the sun, in principle, but our plots predict such a low intensity at the sides of the halo as to be unobservable. For higher sun altitudes, the

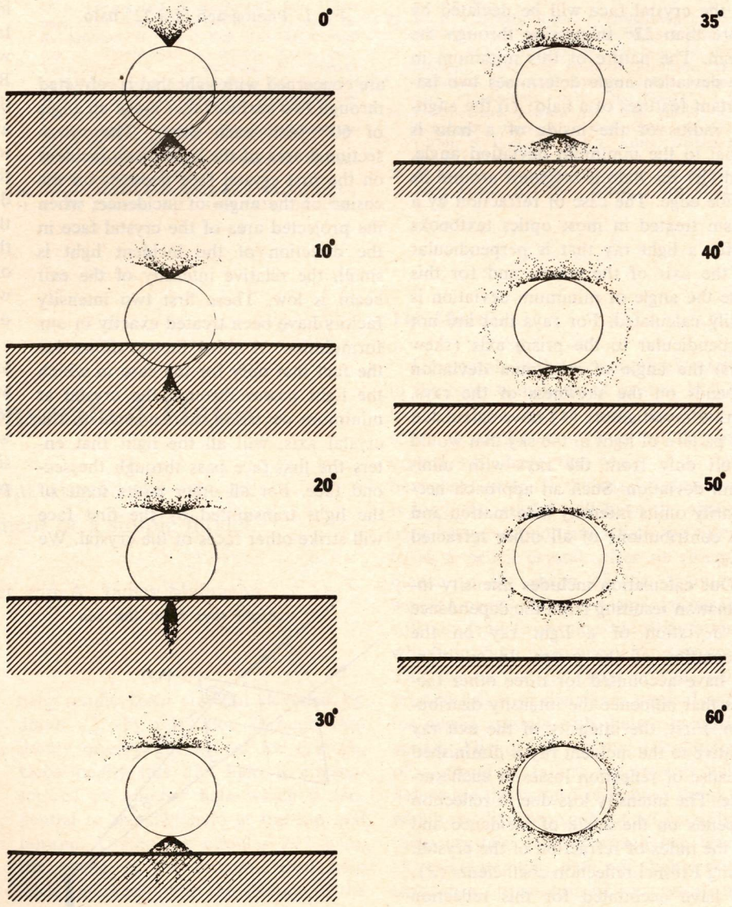


Fig. 6. Simulation of circumscribed halos for various altitudes of the sun, based on the assumption that the ice crystal axes are horizontal. The heavy line represents the horizon, and the circle marks the inner edge of the 22° halo.

circumscribed halo becomes more uniformly intense around its perimeter and shrinks to match the circular shape of the 22° halo.

We have taken photographs with which to compare these predictions, some of which are shown in Fig. 7. Figure 7, C and F (sun altitudes of 25° and 60°), show the 22° halo not as a circle but somewhat horizontally elongated. These two photographs were taken with the camera facing a reflecting glass sphere (*3*), and the resulting distortion is the price one pays for obtaining a photograph which originally covered the entire sky. For altitudes of 0° and 25° (Fig. 7, A and B) the upper tangential arc is essentially complete. It is not expected, even in the most intense display, to continue around to the sides of the 22° halo. For sun altitudes less than 22° the lower tangential arc will be below the horizon, but an observer in an airplane may see it.

The 22° halo and the circumscribed halo can occur independently. Figure 1 illustrates the more common situation in which only the 22° halo is seen. Five of the photographs in Fig. 7 (A, B, C, E, and F) show both halos, but Fig. 7D (for a sun altitude of 40°) shows the upper arc of the circumscribed halo with no trace of the 22° halo. The simultaneous occurrence of both halos could result from groups of ice crystals with different orientation distributions located at different altitudes in the sky; or they might result from two different distributions in the same region of the sky resulting from crystals of different sizes or different length-to-width ratios. Flat plate crystals oriented with their axes nearly vertical will give rise to bright spots located at about 22° away from the sun on either side. These parahelions or "mock suns" are commonly observed. The techniques used in this investigation appear to produce satisfactory simulations of these effects also (*4*).

Fig. 7. Photographs of circumscribed halos for various altitudes of the sun.

Conclusion

The detailed agreement between the form of the circumscribed halo and our simulations for a range of sun altitudes would seem to provide convincing evidence that hexagonal ice crystals with nearly horizontal axes are responsible for this phenomenon. In general, slight deviation from the horizontal will tend to smear the upper and lower arcs out along the 22° halo, the extreme case of deviation from the horizontal resulting in a turning of the circumscribed halo into the 22° halo. Our simulation shows that the features of the circumscribed halo are reproduced by crystals with exactly horizontal axes, no tilt from the horizontal being necessary.

References and Notes

1. J. M. Pernter and F. M. Exner, *Meteorologische Optik* (Braumüller, Vienna and Leipzig, 1910). For a review, in English, of the work by Pernter and Exner, see W. J. Humphreys [*Physics of the Air* (Dover, New York, 1964), pp. 519–524] and M. Minnaert [*The Nature of Light and Colour in the Open Air* (Dover, New York, 1954), p. 197]. For a continuation of this treatment, see R. A. R. Tricker, *Introduction to Meteorological Optics* (American Elsevier, New York, 1970), pp. 108–117.
2. See, for example, M. Born and E. Wolf, *Principles of Optics* (Pergamon, Oxford, ed. 4, 1970), pp. 38–42.
3. The reflecting sphere used to obtain Fig. 7, C and F, is actually a Christmas tree ornament. The composition of Fig. 7C is not intended to imply anything about the character of the senior author who appears in it, but results from an attempt to reduce a lens flare by blocking out the sun.
4. See R. G. Greenler, M. Drinkwine, A. J. Mallmann, G. Blumenthal, *Amer. Sci.*, in press.

Congenital and Genetic Disease in Domestic Animals

Farm and household animals can warn of environmental hazards and provide models of human genetic disease.

John J. Mulvihill

By relying upon standard laboratory species for research in genetics and teratology, scientists may be neglecting clues from other species, particularly domestic animals, such as dogs, cats, cattle, sheep, and swine. I shall describe some recent observations on domestic animals that have led to the identification of environmental teratogens, and have provided insights into the pathogenesis of some congenital defects and genetic diseases in man. Most of the chosen examples are recent, unprobed observations, topical and ripe for investigative effort. Since animal models of human diseases have been the subject of a spate of recent symposia, bibliographies, books, and editorials (*1*), an encyclopedic review is not intended.

Malformations Caused by Plant Toxin

For 50 years, farmers in the western United States accepted, indeed apparently concealed, the fact that each year about 1 percent of ewes would deliver monstrous lambs with midfacial malformations or cebocephaly (Fig. 1A). The defects ranged in severity from cyclopia, through maxillary hypoplasia producing the appearance of a monkey's face, to the slightest irregularity of the upper lip. These deformities, popularly known as chattos, which means monkey face, were not considered hereditary, but occurred only in certain Rocky Mountain herds. In order to preserve a breeder's reputation, the lambs that did not die from asphyxiation caused by the defects were slain and lost to scientific study.

In the late 1950's, an epidemic rise in the frequency of chattos in certain herds led Binns and others of the U.S. Department of Agriculture to investigate the cyclopian sheep. In his initial report in 1959, he and his co-workers described the clinical syndrome and crucial breeding experiments, which excluded recessive inheritance and implicated an environmental agent (*2*). In the next report (*3*) necropsy findings were added and the bluetongue vaccine, which was known to produce stillborn and malformed lambs (*4*), was exonerated. Review of environmental factors failed to implicate nutritional excesses or deficiencies and mineral toxins, but foscused attention on the plant *Veratrum californicum*, which grew only in the high altitude ranges grazed by the affected herds (Fig. 1B) (*5*). The feeding of dried *V. californicum* to ewes at low altitudes during the first month of gestation produced the cyclopian syndrome in the offspring (*6*) and established day 14 of gestation as the specific time of susceptibility (*7*). It was significant that experimental feedings in smaller laboratory animals yielded no cyclopian monsters.

Workers in the same laboratory (*8*) pursued the offending plant substance, turning first to extracted alkaloids and later defining the chemical structures and teratogenic activity of compounds purified from *V. californicum*. The active teratogens were cyclopamine, cycloposine, and jervine, all steroids with a rigidly positioned tetrahydrofurylpiperidine side chain at C-17 (Fig. 1C). Appreciating the role of hormonal modification of gene action, Keeler suggested that the teratogenic mechanism might be a competitive inhibition by cyclopamine of hormones which help initiate RNA synthesis at appropriate times during embryogenesis.

Thus, over 15 years, the secret of a disease occurring to excess in isolated flocks of sheep was revealed by an observant veterinarian and skilled chemist. Although their story is still incomplete, they have contributed greatly to the economic welfare of sheep ranchers and to awareness of yet another class of teratogens.

In particular, this account illustrates one worthwhile use of animal models—for distinguishing genetic from environmental causes in a cluster of similar cases. In man, this question must be settled by epidemiological studies, which may be tedious, time consuming, and often inconclusive. In diseases of domestic animals, on the other hand, epidemiology still provides an initial hypothesis which can be tested quickly by definitive breeding experiments. At present, this type of cranial malformation in sheep is well studied and well known, but has no human homolog because an environmental teratogen has not been identified in cases of cyclopia in man.

Minamata Disease: Mercury Poisoning

A disease of man was delineated not long ago through epidemiologic observations by alert clinicians (*9*). The neurologic ailment, now called Minamata disease, was first described after an epidemic in Japan in the mid-1950's. The cause was poisoning by methylmercury, which was discharged as a by-product from a plastics factory into Minamata Bay, and taken up by fish. Neurologic impairments resulting from the ingestion of poisoned fish were present not only in adults and children—in a familial pattern—but also among the fish themselves and among the fish-eating birds and cats. A smaller epidemic of cerebral palsy among newborn infants was overlooked at first, but proved to be the congenital form of Minamata disease, caused by the ingestion of organic mercury by the pregnant mother who did not develop symptoms.

The lessons on mercury pollution from Japan and elsewhere have been learned slowly in the United States. In New Mexico in early 1970, three out of seven children in the Huckleby family became delirious, blind, and eventually comatose (*10*). The illness had the appearance of an acute, lethal encephalitis, although the specific infectious agent could not be identified. Thorough epidemiological search implicated the grain ingested by the pigs whose meat the children had eaten. This grain had been treated by an organic mercurial called Panogen; the children's sickness was Minamata disease. The mother was in her seventh month of pregnancy when her children first became ill; she remained well, but the boy she delivered had congenital Minamata disease.

While the Japanese experience makes this tragedy all the more devastating, it is especially so since the makings for a similar calamity were reported, but apparently overlooked, 2 years previously (*11*). Here the victims did not include human beings, but the story was quite similar to the New Mexican episode. Pigs on a New York farm suddenly became febrile, anoretic, and listless for 3 to 5 days before dying in coma; some were incoordinate and blind as well. Because several swine had not been vaccinated, hog cholera was initially diagnosed. Necropsy results failed to support that diagnosis, but suggested mercurial poisoning, which toxicologic tests later confirmed. This confirmation came only after seven of the animals had been sold for food. Ultimately, the whole herd died as did other farm animals and birds. During the epidemic, only five piglets were born alive from five litters of 10 to 14 each; the five young pigs died soon after weaning. As in New Mexico, the feed contained wheat grain that had been coated with the mercurial, Panogen. Let us hope, in the face of this overwhelming evidence, that Minamata disease in domestic animals will henceforth be a model for an extinct human disease.

Monitoring the Environment

Minamata disease and cyclopamine-induced cebocephaly are examples of spontaneous diseases whose causes have been shown to be environmental by epidemiologic observations. Teratologic events in one species cannot be extrapolated to all species, but results in animals can hardly be ignored in watching for environmental dangers to man. In fact, because of their place in man's ecology, domestic animals may well be the best sentries for environmental toxins and teratogens. Spontaneously occurring epidemics of congenital malformations among domestic animals should be brought quickly to the attention of biomedical scientists, so that clues to environmental hazards are not overlooked. The report of Minamata disease among pigs on a New York farm could have prevented the outbreak in the family in New Mexico, if regulatory measures had been taken.

One epidemic now deserving prompt elucidation began in 1967 in central Kentucky (*12, 13*). Over 500 pigs on nine farms were born with stiff and deformed joints resembling the human condition of arthrogryposis multiplex congenita (Fig. 2). Genetic causes were considered unlikely because different boars were used. Epidemiologic search was focused on burley tobacco stalks, which were ingested during pregnancy by all the mothers of the malformed swine. The teratogenic agent remains unknown, but might prove to be natural plant chemicals, as suggested by a report of a similar microepidemic in Missouri (*14*), or compounds sprayed on the plants, such as various insecti-

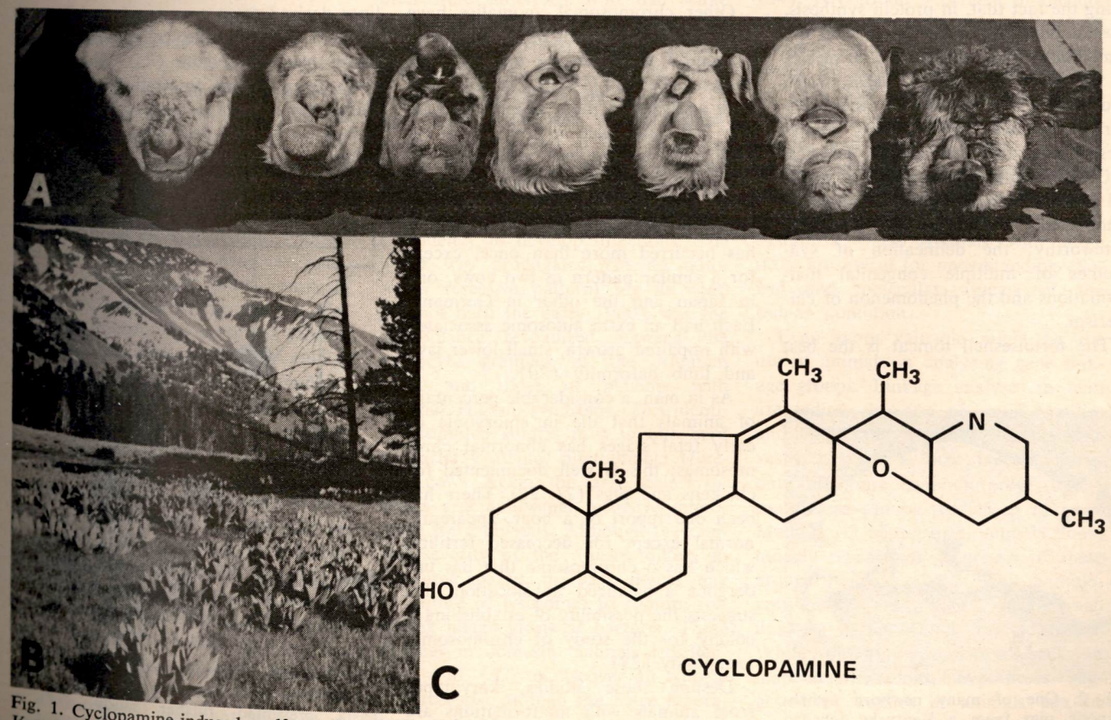


Fig. 1. Cyclopamine-induced malformations in lambs (A). The spectrum of midfacial defects [courtesy of *American Journal of Veterinary Research* (*6*)]. (B) Young *Veratrum californicum* plants in spring in high alpine meadow [courtesy of Dr. W. Binns]. (C) Chemical structure of cyclopamine.

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Table 1. The XXY phenotype in man, sheep, cat, and dog (*17, 18*).

Feature	Man	Sheep	Cat	Dog
Frequency among males	1/350	1/000	?	?
Body size	Tall	Small	Variable	Small
Sterile	Yes	Yes	Usually	Yes
Testicular size compared to normal	One-half	One-ninth	One-half	One-half
Spermatogenesis	Some	None	Rare	None
Testicular histology	Tubular hyalinization	Normal	Prominent interstitium	Tubular dysgenesis
Other defects	Mental deficiency plus behavioral aberrations	Normal "mental" abilities	Tortoiseshell color	Cardiac ventricular septal defect
Buccal smear for chromatin	Positive	Positive	Positive	Positive
Type of late-labeling chromosome	Metacentric*	Acrocentric*	Large submetacentric (*18*)*	Submetacentric*

* This is the same type as the X chromosome of this species.

cides and growth-regulating hormones. It is hoped that these outbreaks of arthrogrypotic pigs can stimulate sufficient research so that rational regulation might prevent an epidemic of human malformations.

Homologous Genetic Diseases

Teratogens may act differently in dissimilar species, and extrapolation of findings in animals to cases of human malformation is hazardous. By contrast, the principles of genetic mechanisms are universal—"even down to the fine print," commented *Nature* in citing the fact that, in protein synthesis, most polypeptide chains begin with the same amino acid, methionine, in species as far apart as bacteria, yeast, trout, and rabbit (*15*). Perhaps no other comparative science enjoys a more fundamental unity than mammalian genetics.

Of the contributions made to medical genetics by comparative mammalian cytogenetics (*16*), two are especially noteworthy: the delineation of syndromes of multiple congenital malformations and the phenomenon of chimerism.

The tortoiseshell tomcat is the best known animal that has one extra X chromosome as do men with Klinefelter's syndrome. The XXY chromosomal complement has been found in at least four species and the similarities of their phenotypes are sufficiently impressive to allow the term "Klinefelter's syndrome" (Table 1) (*17, 18*). On the other hand, the contrasts are intriguing. Why are the sheep and dog with the XXY chromosomes small, while the human XXY individual is tall? Why is there no hyalinization in the postpubertal ovine or canine testes? Our ability to find the answers is not impeded by a lack of experimental models.

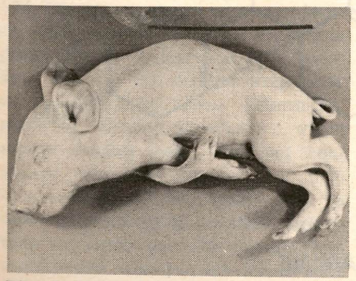

Fig. 2. One of many newborn arthrogrypotic pigs from a Kentucky tobacco farm [courtesy of Dr. M. W. Crowe (*13*)]. Scale 30 cm.

Other chromosomal anomalies have been reported in 2 out of 18 dogs with congenital heart disease and in most domestic species (*19–21*). Chromosomes were analyzed in these animals because they had traits, such as problems of reproductive performance, growth, or development, which have been associated with chromosomal disorders in man. However, no syndrome of anomalies has occurred more than once, except for a similar pattern in two cows, one in Japan and the other in Germany. Each had an extra autosome associated with impaired growth, small lower jaw, and limb deformity (*20*).

As in man, a considerable percentage of animals that die in embryonic or early fetal stages has abnormal chromosomes; this is well documented for chickens and pigs (*21, 22*). There has been one report of a boar, apparently normal except for decreased fertility, which has a chromosome that has undergone a balanced translocation; this suggests the possibility of establishing a colony for the study of chromosomal aneuploidy (*23*).

Despite these studies, karyotypes from animals with malformations are under reported. For example, for eugenic reasons one interesting familial cluster of multiple malformations in Pekingese dogs was lost to further study (Fig. 3) (*24*). Perhaps cytogenetic laboratories should encourage veterinarians to submit specimens. A difficulty which must be tactfully overcome is the reluctance of owners and breeders to allow study of their defective animals. Most owners prefer euthanasia of their animals rather than permit scientific study in order to protect the breeder's reputation.

Chimerism

A mosaic individual has multiple cell lines derived from one zygote, while a chimera has multiple cell lines from more than one zygote (*25*). The chimera, long known to mythology, first found biologic importance when freemartin cattle were described (*26*). The origin of the syndrome has been better

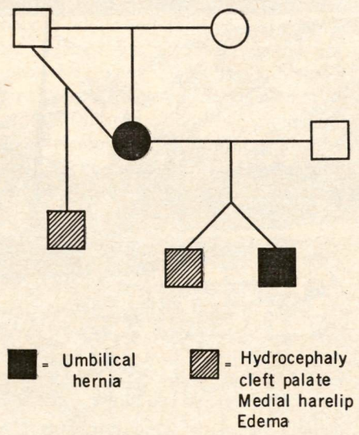

Fig. 3. Familial syndrome of congenital malformations in Pekingese dogs. Euthanasia prevented further study (*18*). Squares represent males, circles represent females.

understood with current cytogenetic analysis. Recognizable as a sterile female, the freemartin results from the intrauterine cross-circulation of blood from a male twin via vascular anastomoses in the placenta. Evidence sustains equally the hypotheses that excessive testosterone from the male sterilizes the female, or that the twins exchange gonadal or blood stem cells which become established in the partners. That the latter event of chimerism sometimes occurs is supported by finding in each twin cells that can be distinguished by histochemical staining, by red cell antigens, or by karyotypes (*27*). Although it is presumed that the placental vascular anomaly occurs less frequently in man than in cattle, at least eight sets of human chimeric twins have been found; thus, chimerism must be considered as an alternate explanation to mosaicism when a patient has two or more cell types. Chimerism, a concept of practical importance in organ transplantation and in the diagnosis of anomalous sexual development, deserves continued study; perhaps one of the best models is the original one—the sterile heifer.

Single Gene Defects

In domestic animals, the number of traits clearly caused by single gene defects is far smaller than would be expected from experience in man. The purist may never accept homology in comparative pathology: the argument can always be advanced that a defective gene is expressed over the background of all other genes, some of which are unique to the species. Yet, some spontaneously occurring animal diseases have been sufficiently studied so as to deserve the claim of homology. Two examples are the Ehlers-Danlos syndrome, inherited as a dominant trait, and the recessive Chediak-Higashi syndrome.

Recently, a heritable disorder of connective tissue in mink and dog was described that resembles the Ehlers-Danlos syndrome in man (*28*). The clinical findings in the animals were lax and hyperextensible joints and skin that was easily stretched, bruised, and scarred. Selective matings and short gestations facilitated the prompt demonstration of an autosomal dominant mode of inheritance. Measurements of the tensile strength and collagen content of the skin suggested a basic defect in the intramolecular cross-linking of collagen, similar to that widely considered responsible for the human condition. Histologically, in both man and the animals, the collagen bundles of the dermis are irregularly smaller and haphazardly ordered with frequent whorl formations. Yet, the elastic fibers in the dog and mink appeared normal in number and appearance—an observation contrasting with the popular notion that elastic fibers are more numerous and abnormal in Ehlers-Danlos syndrome of man (*29*). It is noteworthy that more recent studies in man suggest the abnormal elastic fibers are secondary to the basic collagen defect (*30*). With this new model in mink, dogs, and perhaps in pigs and cattle (*31*) and renewed interest in collagen research, great strides can be anticipated in the understanding of Ehlers-Danlos syndrome, long stagnant from a lack of methods and subjects.

Similar research models may be offered by mink, cattle, and mice which have a condition resembling Chediak-Higashi syndrome (*32*). In 1943, children were described who had white streaks in their hair, photophobia, pale eyes, and most strikingly, a marked proclivity to contract bacterial infections causing death by 7 years of age. Their leukocytes showed abnormally large granules in the cytoplasm. In 1941, a strain of mink, designated Aleutian, arose with unusually light coat color, photophobia, pale eyes, and a tendency to develop infections. The breed was propagated (in an autosomal recessive pattern) for its coat, but not until the early 1960's was the resemblance recognized between the leukocyte granules of the Aleutian mink and those of patients with Chediak-Higashi syndrome. This identity prompted studies in a unique herd of partially albino, photophobic Hereford cows. Again, the large, pale lysosomes and autosomal recessive inheritance were obvious. Although the clinical severity of the disease differs in the three species, the basic defect may be failure of lysosomes to rupture following phagocytosis of bacteria. These findings in domestic animals led Bennett *et al.* (*33*) to discover an autosomal recessive trait in the beige laboratory mouse consisting of pigmentary dilution and giant lysosomes in leukocytes. But the murine condition is a less satisfactory model than that of cattle and mink, for there is no diathesis for infection.

The almost simultaneous discovery of three diverse species manifesting a "new," rare disease points out the likelihood of finding animal homologs to many human diseases caused by single genes. People with diseases of single gene etiology are individually rare and present limited research opportunities. Further understanding of their traits seems worthwhile in order to relieve a disproportionate amount of suffering and to advance general biomedical knowledge that has applications far beyond the few affected individuals. It appears at present that domestic animals deserve wider exploitation.

Genes Linked on the X Chromosome

Comparative study of traits borne on the X chromosome enjoys a theoretical advantage over studies of autosomal traits, namely, the remarkable stability of the genetic content of that chromosome during mammalian evolution (*34*). A constant 5 percent of the nuclear DNA in each mammalian cell seems to be located on the X chromosome. Moreover, the X chromosomes of man and other mammals surely bear homologous genes, thereby providing landmarks for mapping other genes. Comparable genes include those responsible for hemophilias A and B, glucose-6-phosphate dehydrogenase, and cystinuria (*35*). Animals with these traits are useful for understanding clinical and molecular aspects of the human conditions.

Even more valuable might be the use of animals in analyzing gene linkage groups. Linkage analyses in man are tedious because of small families and long generation time. It can take years to prove a loose linkage. Often only the more common protein polymorphisms can be studied in humans. Matings of appropriate animals could quickly reveal linkage groups. If these groups included a locus for a homologous human trait, then a new human linkage group could be suggested. While direct extrapolation back to man is hazardous, hypotheses suggested by studies in animals can be promptly tested in man. For example, the locus for glucose-6-phosphate dehydrogenase has been linked in pigs to

the "H" locus (*36*). If confirmed, this fact should promote a search for the comparable human locus. The efficiency of using animals for linkage analysis has been shown by Hines *et al.* (*37*) in a study of 17 polymorphic loci in 6545 mother-daughter cattle pairs. Four linkage groups, including one triplet, were demonstrated. Hines *et al.* emphasized, in particular, the excellent breeding records which expedited their work.

Polygenic Inheritance

The bulk of human disease that has any significant genetic basis cannot be attributed to a single gene, but to many interacting genes, no one of which is dominant. Such inheritance is known as polygenic or multifactorial. Two common human birth defects, one of the heart and the other the hip, seem to be polygenic traits. Comparative aspects of these diseases are strikingly similar in man and dog (*38–40*). For both species, the overall incidence rate of each defect is two to seven per thousand (*41*). Both defects occur more commonly in purebred dogs and in some breeds the high incidence of heart defects is caused by a single type of malformation which might be considered breed specific (Fig. 4). For example, poodles tend to have patent ductus arteriosus, while German shepherds have a persistent right aortic arch. Increased risk of hip dysplasia is partly a function of larger adult size; thus, St. Bernards have 50 times the risk of miniature or toy poodles, which have twice the risk of mongrels.

Advantages of Domestic Animals

Every species used for research, including man, is a compromise from both theoretical and practical considerations. Animals other than man, however, offer the advantages of experimental control and reproducibility. Their breeding—and inbreeding, to a certain extent—can be regulated. The killing of pregnant animals at specific intervals can quickly clarify the embryogenesis of birth defects.

Domestic animals are not a research panacea. Their size alone might prohibit their use at some institutions, especially if breeding experiments were planned. Compared to laboratory rodents, gestations are longer and litter sizes are smaller; sometimes only one or two offspring are produced per cycle. Equally important is the lack of readily available data on ultrastructural and radiologic anatomy, physiology, and pathology of species or breeds.

What, then, are the advantages of using domestic breeds rather than the usual laboratory animals? First and most important is the fact that their diseases occur spontaneously. Spontaneity indicates only that the condition was not induced experimentally by an exogenous agent; it does not imply that the trait appeared unexpectedly or without genetic manipulation. For example, the classic laboratory model of diabetes mellitus requires the administration of alloxan, while the disease appears spontaneously (but not unexpectedly) in man as well as cattle, cats, and dogs (*42*). Traits that have some aspects of diabetes (such as obesity) appear in mice and rats, but no rodent mimics the human condition exactly because of differences in pathophysiology or genetics (*43*). Intensive breeding solely for laboratory use may artificially maintain not only genes for the pathologic trait but also other linked genes whose effects might be subtle but significant. Random use of farm animals with a sporadic disease would thwart this hazard. The second advantage is that domestic animals are comprised of a greater variety of species and families than are the usual laboratory animals and they are frequently more closely related to *Homo sapiens* phylogenetically. Third, men and domestic animals share similar environments, with the same atmospheric toxins and water pollutants, while laboratory species are protected from these potential teratogens and mutagens. Fourth, the size and docility of domestic animals facilitate repeated measurements and observations of a broad range of parameters, such as blood chemicals, tissue biopsies, placentas, and fetal physiology (*44*). Fifth, the genetic background on which diseases caused by single genes are expressed can be modified. On the one hand, a random genetic background, as would be present in mongrel dogs, would be desirable in studying a single mutant gene. On the other hand, a largely shared gene pool, as in purebreds, would be used for reliably producing traits of polygenic inheritance: for example, congenital defects of the heart and hip are most common in purebred dogs. The fact that inbreeding among domestic animals usually fails would deter their use in fields requiring identical genotypes, such as transplantation research. Sixth, individual breeds can have numerous pathologic traits offering a variety of experimental models in a single breed.

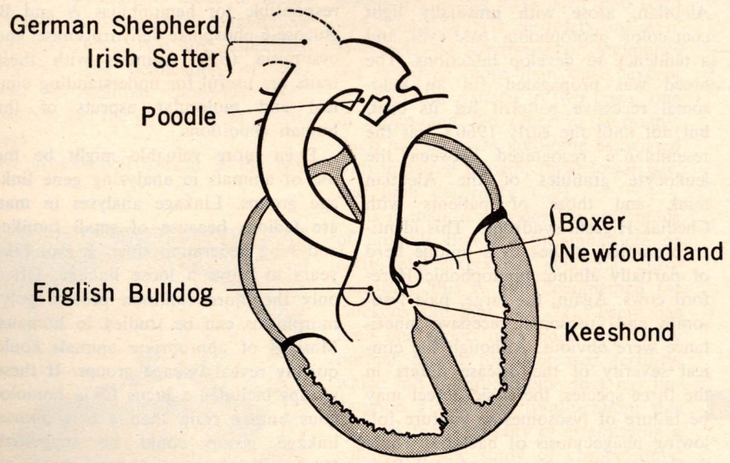

Fig. 4. Breed-specific congenital heart defects in dogs at the School of Veterinary Medicine, University of Pennsylvania, 1958–1965 (*40*). Certain breeds of dogs have significant excesses of specific heart defects ($P < .01$, except English bulldog where $P < .05$). For example, Keeshonds had an excess frequency of ventricular septal defects (as part of tetralogy of Flofallot). Persistence of the right aortic arch was common in German shepherd dogs and Irish setters.

Summary and Recommendations

A large number of experimental models exists throughout the nation in barnyards, kennels, and homes, as well as in clinics of veterinary medical schools. Spontaneously occurring congenital defects in these animals can give life-saving clues to new environmental teratogens of importance to man, such as methylmercury. Their genetic disorders, whether of chromosomal, single gene, or polygenic etiology, provide research opportunities that are often unavailable in the usual laboratory species. The Klinefelter, Ehlers-Danlos, and Chediak-Higashi syndromes, chimerism, congenital heart disease, and congenital hip dysplasia are some human conditions that can be studied in domestic animals. In the past, comparative research on these conditions has been sporadic and fortuitous. While serendipitous discoveries may be of great value, a systematic approach would be more effective.

In order to promote this systematic approach, several programs are now under way:

1) Documentation of the frequency of disease in a defined population of animals (*39, 45*).

2) Simultaneous surveillance of a human and animal population to identify outbreaks of congenital defects that might be caused by a teratogen (*14, 46*).

3) Formal training programs in comparative pathology (*47*).

4) A national exchange of information on animal models (*48*).

Besides these systematic programs, other efforts are equally desirable, but harder to define: (i) establishment of biologic (including radiologic, immunologic, and endocrinologic) standards in each species and breed; (ii) greater awareness of the veterinary literature by biomedical researchers, a state which can be achieved by reading *Current Contents* (*49*) and through library subscriptions to standard veterinary periodicals; and (iii) greater cooperation between animal owners and veterinary scientists, so that potential models are not killed before they are adequately studied.

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49. The Institute for Scientific Information, Philadelphia, publishes weekly issues in one annual volume for each of five scientific fields.

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The Significance of Science

Cultural and social aspects of science and its relation to society are discussed.

Victor F. Weisskopf

And I gave my heart to seek and search out by wisdom concerning all things that are done under heaven. This sore task hath God given to the sons of man to be exercised herewith.—Ecclesiastes 1 : 13.

For in much wisdom is much grief and he that increaseth knowledge increases sorrow.—Ecclesiastes 1 : 18.

The development of science and technology during the last centuries has been very fast and overwhelming. All aspects of human society have been deeply influenced by it, the quality of life has been changed and often gravely disturbed. Today we have become very sensitive to the problems raised by this fast development, and we are faced with important questions regarding the role of science in society.

Science is under severe attack from some quarters; it is considered a panacea for the cure of all ills by others. I will sketch here three positions in regard to science that characterize some of the common attitudes toward this problem.

Position 1. Many branches of science have grown excessively during the recent decades; too large amounts of public support and too much scientific manpower are devoted to esoteric research in fields that have little to do with practical problems. Only such scientific research should be supported as that promising reasonable payoff in terms of practical applications for industry, public welfare, medicine, or national defense. Science as a study of nature for its own sake is appreciated by only a few people and has very limited public value. Its support should be reduced to a much more modest scale.

Position 2. Most of today's scientific research is detrimental to society because it is the source of industrial innovations, most of which have led and will lead to further deterioration of our environment, to an inhuman computerized way of life destroying the social fabric of our society, to more dangerous and destructive applications in weaponry leading to wars of annihilation, and to further development of our society toward Orwell's world of 1984. At best, science is a waste of resources that should be devoted to some immediate, socially useful purpose.

Position 3. The methods and approaches used in the natural sciences and in technology—the so-called scientific method—has proved overwhelmingly successful in resolving problems, in elucidating situations, in explaining phenomena of the natural world, and in attaining well-defined aims. It should be extended to all problems confronting humanity because it promises to be as successful in any area of human endeavor and human interest as it has been in the realm of natural science and technology.

These three positions are, to a large extent, mutually exclusive. They point in three almost orthogonal directions. In this essay I contend that each of these positions takes a narrow and one-sided view of the role of science in human society. Science is involved in man's thought and action in many different and often contradictory ways. Science must coexist with other forms of human urges, feelings, and self-realizations. Science is based on a very fundamental human urge: man's innate desire to know and understand the universe in which he lives and to gain insight into the driving forces that govern the world around us. This urge is paired with another one: the desire to improve the precarious conditions of human existence in a hostile world, in a hostile natural environment, and in hostile societies. Man desires to influence and to change the material and social conditions of life with the help of acquired knowledge and experience, which, in modern times, are mainly derived from science. As in all human situations, the urges and desires do not always lead to actions that serve the intended purposes, and the intended purposes are not always such that real benefits accrue for the people involved. These are the basic elements for our discussion of the role of science in human affairs.

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Basic Science and Practical Applications

Let us return to position 1, the excessive cost of basic science. It is based on the supposition that most of research is unimportant and irrelevant if it is carried out without regard to practical applications. It is commonplace that technology and medicine owe an enormous debt to the study of nature for its own sake, that is to basic science. It is hardly necessary to mention here the many instances which prove that modern industry and modern care for the sick are based on past results of basic science. Nor is basic science such an expensive luxury when its cost is compared with its services. The total cost of all basic science from Archimedes to the present day is probably near $30 billion (*1*), less than 12 days' worth of production of the United States whose gadgets and machines are to a large extent the product of earlier scientific achievement. The practical value of those parts of pure science which seemingly have no immediate connections with applications has been clearly brought out by H. B. G. Casimir, who collected a number of interesting examples of how decisive technical progress was made by scientists who did not work at all for a well-defined practical aim (*2*):

> I have heard statements that the role of academic research in innovation is slight. It is about the most blatant piece of nonsense it has been my fortune to stumble upon.
>
> Certainly, one might speculate idly whether transistors might have been discovered by people who had not been trained in and had not contributed to wave mechanics or the theory of electrons in solids. It so happened that inventors of transistors were versed in and contributed to the quantum theory of solids.
>
> One might ask whether basic circuits in computers might have been found by people who wanted to build computers. As it happens, they were discovered in the thirties by physicists dealing with the counting of nuclear particles because they were interested in nuclear physics.
>
> One might ask whether there would be nuclear power because people wanted new power sources or whether the urge to have new power would have led to the discovery of the nucleus. Perhaps—only it didn't happen that way, and there were the Curies and Rutherford and Fermi and a few others.
>
> One might ask whether an electronic industry could exist without the previous discovery of electrons by people like Thomson and H. A. Lorentz. Again, it didn't happen that way.
>
> One might ask even whether induction coils in motor cars might have been made by enterprises which wanted to make motor transport and whether then they would have stumbled on the laws of induction. But the laws of induction had been found by Faraday many decades before that.
>
> Or whether, in an urge to provide better communication, one might have found electromagnetic waves. They weren't found that way. They were found by Hertz who emphasized the beauty of physics and who based his work on the theoretical considerations of Maxwell. I think there is hardly any example of twentieth century innovation which is not indebted in this way to basic scientific thought.

Some of these examples are evidences of the fact that experimentation and observation at the frontier of science require technical means beyond the capabilties of ordinary technology. Therefore, the scientist in his search for new insights is forced and often succeeds to extend the technological frontier. This is why a large number of technologically important inventions had their origin not in the desire to fulfill a certain practical aim but in the attempts to sharpen the tools for the penetration of the unknown.

The examples quoted are taken from past developments and it is frequently asserted that some branches of modern fundamental science are so far removed from the human environment that practical applications are most improbable. In particular, the physics of elementary particles and astronomy are considered to be in this category. These sciences deal with far-off objects; elementary particles in the modern sense are also "far off," because mesons and baryons appear only when matter is subject to extremely high energy which is commonly not available on Earth but probably occurs only at a few distant spots in the universe. The "far off" feature of these sciences is also what makes them expensive. It costs much money to create in our laboratory conditions that may be realized only in some exploding galaxy. It costs much to build instruments for the study of the limits of the universe. The argument against these sciences is that they are dealing with subjects far removed from our human environment and that therefore they are of minor relevance.

Let us consider the question of what constitutes the human environment. Ten thousand years ago there were no metals in the human environment. Metals rarely are found in pure form in nature. But after man had found out how to create them from ores, metals played an important role in our environment. The first piece of copper must have looked very esoteric and useless. In fact, man used it for a long time only for decorative purposes. Later, the introduction of this new material into man's ken gave rise to interesting possibilities that ultimately led to the dominant role of metals in his environment. In short, we have created a metallic environment. To choose another example, electricity appears rarely in nature in observable forms; for example, only in lightning discharges and in frictional electrostatics, which is not an important part of the human environment. After long years of research into minute effects, it was possible to recognize the nature of electric phenomena and then to find out what dominant role they play in the atom. The introduction of these new phenomena into the human world created a completely new electric environment in which we live today with 120-volt outlets in every wall. The most recent example is in nuclear physics. In the early days, prying into the problems of nuclear structure was considered a purely academic pursuit, directed only toward the advancement of knowledge concerning the innermost structure of matter. Rutherford said in 1933, "Anyone who expects a source of power from transformation of these atoms is talking moonshine." His conclusion was based on the same reasoning: The nuclear phenomena are too far removed from our human environment. True enough, apart from the rare cases of natural radioactivity, nuclear reactions must be artificially created at high cost with energetic particle beams. Most nuclear phenomena on Earth are man-made; they occur naturally only in the center of stars. Here again, the introduction of these man-made phenomena into our human world has led to a large number of interactions. Artificial radioactivity has revolutionized many branches of medicine, biology, chemistry, and metallurgy; the process of fission is an ever-increasing source of energy, for the better or the worse. Nuclear phenomena are now an important part of a new human environment.

These examples show the weakness of the argument that certain natural phenomena are too far removed to be relevant to the human environment. Natural laws are universal; in principle, any natural process can be generated on Earth under suitable conditions. Modern instruments did create a cosmic environment in our laboratories when they produced processes that do not ordinarily take place in a terrestrial environment. Astronomy and particle physics deal with previously unknown and mostly unexplained phenomena. There is every possibility that some of them one day could also be reproduced on Earth in some form or another and be applied in a reasonable way for some useful purpose. Today already some special medical effects have been found for pion beams, effects that cannot be brought about by any other means. Purcell (*3*) once said about the applicability of frontier fields such as particle physics: "In our ignorance, it would be presumptuous to dismiss the possibility of useful application as it would be irresponsible to guarantee it."

One cannot divide the different branches of science into those that are important for practical applications and others that are not. The primary aim of science is not application, it is gaining insights into the causes and laws which govern natural processes. But a better understanding of a natural process almost always leads to possibilities of influencing it, or of influencing other processes related to the one that was investigated. The further science developed, the more relations between seemingly unrelated processes were discovered. The study of the solar corona, a phenomenon far off the earth, may lead to a better understanding of the behavior of highly ionized gases in magnetic fields, a topic of great technological importance. These relations between pure and applied science are part of the many-sided involvement of science in all aspects of human endeavor, from the urge to know more about the environment to the desire to improve and to dominate it.

Basic Science and Today's Problems

Position 2 is the expression of an attitude that makes science bear the brunt of public reaction against the mounting difficulties of modern life. This is not the place to analyze the predicaments of modern civilization whose difficulties are related to the increased rate of technological expansion, a rate that today has seemingly reached a critical value in both time and space. With regard to time, the changes in our way of life are now so rapid that marked differences are observable within one generation. This is a new and unsettling phenomenon for mankind; the experiences of the older generation are no longer as useful as they once were in coping with the problems of today. With regard to space, the effects of technology on our environment are no longer small; the parts of the earth's surface, of the water, of the air, which are changed by man or could be destroyed by man are no longer negligible compared to those left untouched. These are unexpected and disturbing consequences with which we do not yet know how to deal.

Since technology, particularly the increasing rate of technological change, is based largely upon science, it is not surprising that science is blamed for its difficulties. An obvious reaction to this situation would be to declare a moratorium on science; this would supposedly stop technological innovation and give us time to settle the problems that are already with us, instead of creating new ones. Recent cuts in scientific support reflect this attitude to some extent. We intend to refute, not the facts on which position 2 is based, but the conclusions drawn from that position.

The call for a moratorium in science is based on its inexorable way of progressing; one discovery leads to many others, and it seems impossible to prevent the application of new discoveries to unintentionally destructive purposes and socially detrimental technologies. Must we conclude, therefore, that it is harmful to continue the search for further knowledge and understanding of the world in which we live? It would seem that this search should be valuable under any circumstances, since knowing less about the world should hardly be better than knowing more.

Ignorance is of no value in itself; cruelty of man against his fellow man or thoughtless exploitation of man and nature existed before the industrial revolution. To stop the growth of scientific knowledge would not prevent its abuses, but it would deprive us of finding new means for avoiding them and deprive us also of an important source of philosophical insight. New scientific knowledge is neither good nor bad. New knowledge usually leads to a better way of predicting consequences and sometimes also to an ability to do something that one could not do before. It will be applied for good or for bad purposes, depending on the decision-making structure of the society, just as in the case of any social and political measure. In this respect science and technology are not different from other human activities.

Today it is fashionable to emphasize the negative aspects of technological progress and to take the positive aspects for granted. One should remember, however, that medical science has doubled the average life span of man, has eliminated many diseases, and has abolished pain in many forms. It has provided the means of effective birth control. The so-called "green revolution" created the potential to eliminate starvation among all presently living people. This is a scientific-technical achievement of momentous significance, even though the actual situation is a far cry from what could be achieved. One should also remember the developments in transportation, construction, and power supply provided by modern technology and their great potentialities for improving the quality of life.

The trouble comes from the fact that, in too many instances, technology has not achieved that purpose. On the contrary, it has contributed to a definite deterioration of life. Medicine may have abolished pain, but modern weapons are producing wholesale pain and suffering. Medical progress has achieved a great measure of death-control which has caused a population explosion; the available means of birth control are far from being effectively used. The blessings of modern medicine are unevenly distributed; lack of adequate medical care for the poor in some important countries causes mounting social tensions. The green revolution produces ten times more food than before, but the distribution is so uneven that starvation still prevails in many parts of the globe; furthermore, the massive use of fertilizers causes eutrophication of many waters. Power production and the internal combustion engine as a means of transportation have polluted the atmosphere. Is it really impossible to avoid harmful effects when we apply our knowledge of natural processes for practical purposes? It should not be so.

There are two distinct sides to these problems: the social and political aspect and the technical aspect. In some instances the technical aspects do not pose any serious problems. The most important example is the use of technology for war or suppression. The only way to prevent the application of scientific results to the development of weapons is to reduce and prevent armed conflicts; certainly, this is a sociopolitical problem in which scientists and nonscientists should be equally interested, but it is not per se a problem of natural science. Other more benign examples are the problems of congested transportation, of city construction, and of some, but not all, of the problems of pollution. In these cases we know what causes the trouble and we know what measures can be taken to avoid it. But we don't know how to convince people to accept these measures. The problems are political and social. The natural scientists cannot help except by pointing out as clearly as possible what the consequences of certain actions or inactions will be. It is beyond the scope of this article to discuss whether it is possible to resolve these political and social problems. We take the only possible attitude in this dilemma: We assume that there will be a solution at some time, in some form, to some of these problems.

However, there are also many detrimental effects of technology of which the physical causes or the remedies are not known to a sufficient degree. Many detrimental effects of industrialization upon the environment belong in this category; among these are carbon dioxide production, long-range influences on atmospheric currents and on climatic conditions, the influence of urbanization on health, the problem of better means of birth control, and many more. Here science has enormous tasks to do in discovering, observing, and explaining unexplored phenomena, relations, and effects. The problems deal with our natural environment and therefore necessarily pose prime questions pertaining to natural science.

What role does basic science play in these efforts? One could conclude that the tasks are for applied science only and that research for its own sake, research that is not directed toward one of the specific problems, is not necessary. It may even be harmful since it takes away talented manpower and resources. This is not so. The spirit of basic research is composed of the following elements: an interest in understanding nature; an urge to observe, to classify, and to follow up observed phenomena for the sake of the phenomena themselves; a drive to probe deeper into a subject by experimenting with nature, by using ingenuity to study phenomena under special and unusual conditions—all in order to find connections and dependencies, causes and effects, laws and principles.

This attitude of basic research is necessary for the solution of today's pressing problems because it leads people to search for causes and effects in a systematic way, regardless of any ulterior aim. Many of today's troubles are caused by unforeseen consequences of human action on the environment, by interference with the natural cycle of events. The effects of accumulated technological developments are about to cover the entire surface of the earth. We face a complicated network of physical, chemical, and biological causes and effects, many of them only partially understood. Much painstaking basic research will be required before these problems can be tackled efficiently. If technical solutions are introduced before the conditions are thoroughly understood, one may well worsen the situation in the attempt to improve it.

Why is basic research needed for this kind of training? Why couldn't one train people directly by putting them to work on socially pressing problems? Those who ask these questions compare the situation with teaching Greek and Latin to youngsters in order to give them experience in learning foreign languages. The comparison is fallacious. Polanyi (*4*) has expressed the reason most lucidly:

> The scientific method was devised precisely for the purpose of elucidating the nature of things under more carefully controlled conditions and by more rigorous criteria than are present in situations created by practical problems. These conditions and criteria can be discovered only by taking a purely scientific interest in the matter, which again can exist only in minds educated in the appreciation of scientific value. Such sensibility cannot be switched on at will for purposes alien to its inherent passion.

There are two sides to the argument. One concerns the analysis of a situation, and the other concerns the search for ways to improve it. The attitude engendered by pure science is most conducive to getting a clearer picture of the facts and the problems that may have to be faced in coping with air pollution, the population explosion, or the effects of technical innovations upon our environment. In basic science the search is for phenomena and connections in all possible directions, whereas in applied science the search is directed toward a specific goal.

Furthermore, when new technical ideas are needed—and they will be needed—the attitude of basic science is that of looking more toward innovative ideas and less toward the application of known devices because the problems at the frontier are exactly those that cannot be solved with established methods. In basic research a pool of young men and women is formed who are accustomed to tackle unexplained phenomena and who are ready to find new ways to deal with them. They are trained to work under the most exacting conditions in open competition with the scientific world community. Instead of "environmentalists" we should train physicists, chemists, geologists, and biologists capable of dealing with the problems of environment.

Whenever large practical projects have been carried out under emergency conditions—projects that were apparently immensely difficult or impossible—scientists from basic fields have played a decisive role. In the past most of the examples have come from war-related projects, such as the development of radar or the atomic bomb. There is no doubt, however, that this kind of development can be transferred to more constructive problems. In fact, many basic scientists have made important contributions toward a solution of the arms control problem. Their activities have initiated the discussions that led to the halt of bomb tests. Today they are deeply involved in environmental problems.

Two qualifications are in order. Today's problems certainly will require the methods and results of natural science, but they cannot be solved by these methods alone. As was mentioned earlier, the problems are to a great extent social and political, dealing with the behavior of man in complicated and rapidly evolving situations. These are aspects of human experience to which today's methods of natural science are not applicable. Seen within the framework of that science, these phenomena exhibit a degree of instability, a multidimensionality for which our present scientific thinking is inadequate and to which such thinking must be applied with circumspection. There is great temptation to transfer the methods that were so successful in natural science directly to social or political problems. This is not possible in most cases. Different methods may be developed in the future. The social sciences are working hard at the task.

The second qualification concerns the need for scientists trained in basic science. We do not argue that only those trained in basic science can solve our problems to the exclusion of others. Far from it; a collaboration between all kinds of people is needed—basic and applied scientists, engineers, physicians, social scientists, psychologists, lawyers, and politicians. The argument submits that people trained in basic science will play an important and irreplaceable role. They are necessary, but not sufficient. But their necessity emphasizes the importance of keeping basic science activities alive.

To keep basic science vigorous is today much harder than it was in the past; it would be harder even if the financial support were as generous as before. The reason is quite natural; the world situation has become so serious that many scientists or potential scientists find it difficult to worry about some unexplained natural phenomena or undiscovered laws of nature when there are more immediate things to worry about. Some scientists feel that we are in an emergency situation and that we should stop basic science for the duration as we did during World War II. But the war lasted only 4 years for the United States, while the present crisis will endure for at least two decades. If we cripple basic science today, it will not be long before there will be no new generations of devoted young scientists for the tests that mankind must face in the future.

Limitations of Science

Another motivation for the antiscience attitude expressed by position 2 is connected with widespread critical view of science and the ways of thinking it fosters. In this view, science is considered as materialistic and inhuman, as an instrument of defining everything in terms of numbers and thus excluding and denying the irrational and emotive approach to human experience. Value judgments, the distinction between good and evil, and personal feelings supposedly have no place in science. Therefore, it is said, the one-

sided development of the scientific approach has suppressed some most important and valuable parts of human experience in that it has produced an alienated individual in a world dominated by science and technology in which everything is reduced to impersonal data.

The foregoing arguments are diametrically opposite to the views expressed in position 3, which contends that the supposedly rational, inemotive approach of science is the only successful way to deal with human problems of all sorts. Many of today's trends against science are based on the feeling that the scientific view neglects or is unable to take into account some of the most important experiences in human life.

This widely held belief seems to be in contradiction to the claim of "completeness" of science, which is the basis of position 3. It is the claim that every experience—whether caused by a natural phenomenon or by a social or psychic circumstance—is potentially amenable to scientific analysis and to scientific understanding. Of course, many experiences, in particular in the social and psychic realm, are far from being understood today by science, but it is claimed that there is no limit in principle to such scientific insights.

I believe that both the defenders and the attackers of this view could be correct, because we are facing here a typical "complementary" situation (*5*). A system of description can be complete in the sense that there is no experience that does not have a logical place in it, but it still could leave out important aspects which, in principle, have no place within the system. The most famous example in physics is the complementarity between the classical description and the quantum properties of a mechanical system. The classical view of an atom is a little planetary system of electrons running around the nucleus in well-defined orbits. This view cannot be disproved by experiment; any attempt to observe accurately the position of an electron in the atom with suitable light beams or other devices would find the electron there as a real particle, but the attempt to observe it would have destroyed the subtle individuality of the quantum state which is so essential for the atomic properties. Classical physics is "complete" in the sense that it never could be proven false within its own framework of concepts, but it does not encompass the all-important quantum effects. There is a difference between "complete" and something we may call "all-encompassing."

The well-known claim of science for universal validity of its insights may also have its complementary aspects. There is a scientific way to understand every phenomenon, but this does not exclude the existence of human experiences that remain outside science. Let us illustrate the situation by a simple example: How is a Beethoven sonata described in the realm of science? From the point of view of physics, it is a complicated quasi-periodic oscillation of air pressure; from the point of view of physiology it is a complicated sequence of nerve impulses. This is a complete description in scientific terms, but it does not contain the elements of the phenomenon that we consider most relevant. Even a psychological study in depth of what makes the listening to these tone-sequences so exciting cannot do justice to the immediate and direct experience of the music.

Such complementary aspects are found in every human situation. There exist human experiences in the realms of emotion, art, ethics, and personal relations that are as "real" as any measurable experience of our five senses; surely the impact of these experiences is amenable to scientific analysis, but their significance and immediate relevance may get lost in such analysis, just as the quantum nature of the atom is lost when it is subject to observation.

Today one is rather unaccustomed to think in those terms because of the rapid rise of science and the increasing success of the application of scientific ideas to the manipulation of our natural environment in order to make the process of living less strenuous. Whenever in the history of human thought one way of thinking has developed with force, other ways of thinking become unduly neglected and subjugated to an overriding philosophy claiming to encompass all human experience. The preponderance of religious thought in medieval Europe is an obvious example; the preponderance of scientific thought today is another. This situation has its root in a strong human desire for clear-cut, universally valid principles containing the answers to every question. However, the nature of most human problems is such that universally valid answers do not exist, because there is more than one aspect to each of these problems. In either of the two examples, great creative forces were released, and great human suffering resulted from abuses, exaggerations and from the neglect of complementary ways of thinking.

These complementary aspects of human experience play an important role when science is applied to practical aims. Science and technology can provide the means and methods to ease the strain of physical labor, to prolong life, to grow more food, to reach the moon, or to move with supersonic velocity from one place to another. Science and technology are needed to predict what would be the effects of such actions on the total environment. However, the decisions to act or not to act are based on judgments that are outside the realm of science. They are mainly derived from two strong human motives: the desire to improve the conditions of life, and the drive for power and influence over other people. These urges can perhaps be scientifically explained by the evolution of the human race, but they must be regarded as a reality of human experience outside the scientific realm. Science cannot tell us which of the urges is good or bad. Referring to the first rather than the to the second urge, Archibald MacLeish has put this idea into verse: "No equation can divine the quality of life, no instrument record, no computer conceive it/only bit by bit can feeling man lovingly retrieve it."

The true significance of science would become clearer if scientists and nonscientists were more aware of the existence of these aspects that are outside the realm of science. If this situation were better appreciated, the prejudice against science would lose much of its basis and the intrinsic value of our growing knowledge of natural phenomena would be much better recognized.

Intrinsic Value of Science

Since the beginnings of culture, man was curious about the world in which he lives and eager to explain it. The explanations have taken different forms—mythologic, religious, or magic—and they usually encompass all and everything from the beginning to the end. About 500 years ago man's curiosity took a special turn toward detailed experimentation with nature. It was the beginning of science as we know it today. Instead of reaching directly at the whole truth in an explanation for the entire universe—its creation and present form—it tried to acquire partial truths in a small measure about some definable and reasonably separable group of phenomena. Science developed only when men began to refrain from asking general questions such as: What is matter made of? How was the universe created? What is the essence of life? Instead, they asked limited questions, such as: How does an object fall? How does water flow in a tube? Thus, in place of asking general questions and receiving limited answers, they asked limited questions and found general answers. It remains a great miracle, that this process succeeded, and that the answerable questions became gradually more and more universal. As Einstein said: "The most incomprehensible fact is that nature is comprehensible."

Indeed, today one is able to give a reasonably definite answer to the question of what matter is made of. One begins to understand the essence of life and the origin of the universe. Only a renunciation of immediate contact with the "one and absolute truth," only endless detours through the diversity of experience could allow the methods of science to become more penetrating, and their insights to become more fundamental. It resulted in the recognition of universal principles such as gravitation, the wave nature of light, the conservation of energy, heat as a form of motion, the electric and magnetic fields, the existence of fundamental units of matter, the living cell, the Darwinian evolution. It reached its culmination in the 20th century with the discovery of the connections between space and time by Einstein, the recognition of the electric nature of matter and of the principles of quantum mechanics; the 20th century yielded some answers of how nature manages to produce specific materials, qualities, shapes, colors, and structures, and gave rise to new insights into the nature of life as a result of the development of molecular biology. A framework has been created for a unified description and understanding of the natural world on a cosmic and microcosmic level, and its evolution from a disordered hydrogen cloud to the existence of life on our planet. This framework allows us to see fundamental connections between the properties of nuclei, atoms, molecules, living cells, and stars; it tells us in terms of a few constants of nature why matter in its different forms exhibits the qualities we observe. The scientific insight is not complete, it is still being developed; but its universal character and its success in disclosing the essential features of our natural world makes it one of the great cultural creations of our era.

As part of our culture it has much in common with the arts; new forms and ideas are created in order to express the relations of man to his environment. However, the influence of science on society and on our lives and our thinking is much greater today in the positive and negative sense. There were times in the past in which the arts had a similar influence. Science is a unique product of our period.

Science differs from contemporary artistic creations by its collective character. A scientific achievement may be the result of the work of one individual, but its significance rests solely on its role as a part of a single edifice erected by the collective effort of past and present generations of scientists. This effort was and is made by scientists all over the world; the character of the contributions does not reflect their national, racial, or geographic origin. Science is a truly universal human enterprise; the same questions are asked by all men involved in science, the same joy of insight is experienced when a new aspect of deeper coherence was found in the fabric of nature. The choices of problems and the directions of research at the frontier of fundamental science depend much less on the economic, social, and political needs than most people assume; they are determined mainly by the instrumental possibilities of observation and by the internal logics of fundamental science itself. This is not so in applied science and technology which obviously are much more—though not completely—subject to societal demands of all kinds. The rapid developments of applied electronics and acoustics during World War II were certainly determined by military needs. But there are exceptions on both sides. The progress in nuclear physics and in plasma physics—these are to a large extent fundamental branches—was certainly much accelerated by the possibilities of practical applications to power production by nuclear fission or fusion. The invention of the transistor—an example of applied physics—was not prompted by its practical potentialities.

It is often difficult to distinguish between fundamental and applied science, and any considerations of this kind can lead to dangerous oversimplifications. The success of basic research derives to a large extent from the close cooperation of basic and applied science. This close relation provided tools of high quality, without which many fundamental discoveries could not have been made.

Compared to other groups the scientific community is more international or, better, more supranational because it transcends national and political differences. Personal contacts across borders are established easily between people working on similar problems; science has its own international language. The percentage of foreigners in scientific laboratories is probably greater than in any other human activity; there are some very successful international laboratories, among which CERN in Geneva stands out in the field of high-energy physics, as a model for the future United States of Europe. The international ties of science have been helpful even in nonscientific affairs; for example, in the so-called Pugwash conferences, scientists initiated a number of actions directed toward a more unified world, such as the ending of atomic bomb tests in the atmosphere and the beginning of serious talks on arms control.

Science has a peculiar relation to the traditional and the revolutionary. It is both traditional and revolutionary at the same time. Newton's mechanics and the electrodynamics of Faraday and Maxwell are still valid and alive. Current calculations of satellite orbits and of radio waves are still based on them. Revolutionary concepts, such as that of relativity and quantum theory did not invalidate the earlier ideas; they establish unexpected limitations to the old ideas, which remain valid within these limitations. On the other hand, there is a strong trend in science toward the new and the different. Technological advances and novel ways of thinking are constantly introduced to change the manner of working and the method of approach. But scientific revolutions are extensions rather than replacements. Apart from a few notable exceptions, old ideas are expanded and reinterpreted on a more universal basis. Old methods are proved not wrong, but impractical and inaccurate.

In many ways, the attitude of mind in science is opposed to some of the negative and destructive trends in today's thinking. It means being involved in activities where there is real progress; deeper and deeper insights into the

natural world are continually obtained. It engenders a feeling of participation at a unique collective enterprise, the construction and improvement of a vast intellectual edifice, one of the great creations of contemporary culture. There is little dispute among scientists regarding the general value scale as to what is significant and as to the directions in which to proceed, although there are differences of opinion regarding the relative importance of different elements.

Scientific knowledge leads to an intimate relation between man and nature, to a closer contact with the phenomena derived from a deeper understanding. To know more about the laws and the fundamental processes on which the material world is based should lead to a deeper appreciation of nature in all its forms. It should show how natural events are closely interwoven and depend on each other, how almost every mineral structure and certainly every manifestation of life are unique and irreplaceable. Thus, science establishes an awareness of how the universe, the atom, and the phenomena of life coexist and are all one. It is ecology in its widest interpretation.

There are still many fascinating problems and unanswered questions at all frontiers of science. We are not yet skillful enough to deal with complexity in nature. Even the structure of liquids is not well understood. No physicist would have predicted the existence of a liquid state from our present knowledge of atomic properties. The complexity of living matter presents far greater problems. In spite of the growing insight into the fundamental processes of reproduction and heredity, we still know very little about the development of organisms, about the functioning of the nervous system, and we know practically nothing about what goes on in the brain when we think or when we use the memory. The deeper we penetrate into the complexities of living organisms, into the structure of matter, or into the expanses of the universe, the closer we get to the essential problems of natural philosophy: How does a growing organism develop its complex structure? What is the significance of the particles and subparticles of which matter is composed? What is the origin of matter? What is the structure and the history of the universe at large?

The urge to find answers to questions of the nature of life and matter and to pursue the search for laws and meaning in the flow of events is the mainspring and the most important justification of science. These problems may have little to do with the immediate needs of society, but they will always be in the center of interest because they deal with the where, whence, and what of material existence.

Obligations of the Scientist

Does the actual science establishment correspond to the ideal picture of science as we have drawn it? It certainly does not appear so to many observers outside of the scientific community and even to some scientists. The human problems caused by the ever-increasing development of a science-based technology are too close and too threatening; they overshadow the significance of fundamental science as a provider of deeper insights into nature. The scientist must face the issues raised by the influence of science on society. He must be aware of the social mechanisms that lead to the specific uses and abuses, and he must attempt to prevent the abuses and to increase the benefits of scientific discoveries. Sometimes he must be able to withstand the pressures of society toward participation in activities which he believes to be detrimental. This is not an easy task since the problems are to a great extent of social nature, and the motivations are often dictated by material profit and political power. It puts the scientist in the midst of social and political life and strife.

On the other side, the scientist also has an obligation to be the guardian, contributor, and advocate of scientific knowledge and insight. This great edifice of ideas must not be neglected during a time of crisis. It is a permanent human asset and important public resource. The scientist who devotes his time to the solution of our social and environmental problems does an important job. But so does his colleague who goes on in the pursuit of basic science. We need basic science not only for the solution of practical problems, but also to keep alive the spirit of this great human endeavor. If our students are no longer attracted by the sheer interest and excitement of the subject, we were delinquent in our duty as teachers. We must make this world into a decent and livable world, but we also must create values and ideas for people to live and to strive for. Arts and sciences must not be neglected in times of crisis; on the contrary, more weight should be given to the creation of aims and values. And it is a great value to broaden the territory of the human mind by studying the world in which we live.

Much can and should be improved in the style and character of scientific teaching and research. The rapid increase of science activities during the 1950's and 1960's has left its mark on scientists and science students. Some of the positive aspects have been adulterated; in many respects, science has become an organization for producing new results as fast as possible. Changes and new perspectives are in order. One of the most dangerous aspects in today's scientific life is overspecialization. There are several trends that lead to it. One is the increasing pace of research, which does not allow the researcher enough time to be interested in other fields not directly related to his own. He has enough trouble in trying to stay ahead of his numerous competitors in his own field and cannot devote much time to anything else. Another impetus has been the general availability of research jobs in all fields; therefore the young scientist did not see the necessity of training himself in fields outside his speciality. Our educational system did not produce "physicists," it produced high-energy physicists, solid-state physicists, enzyme biochemists, and so forth. A typical symptom of this disease can be found in the manpower questionnaire that the National Science Foundation circulated among physicists, where one is asked to specify one's field which is subdivided to the extreme. For example, there are divisions of this kind: elementary particles, hadrons; elementary particles, leptons; solid-state, magnetic properties; solid-state, optical properties. . . . And people try to find a job in exactly the sub speciality of their Ph.D. thesis. What a narrow view and what a boring life with the same subfield of physics forever! A physicist should be interested in all of physics and should welcome a change of field. Most of the positive aspects of science come from an awareness of its broad range, of its universal view. The same quantum theory governs elementary subparticles and phonons or excitons in a solid.

The teaching of science must return to the emphasis on the unity and universality of science, and should become broader than the mere attempt to produce expert craftsmen in a specialized trade. Surely, we must train competent experts, but we also must bring fields together and show the connections between different fields of science. This task may be difficult because of heavy demands on the time and the intellectual capacities of those involved in modern research. But it is highly rewarding from any point of view. The teacher will get a deeper satisfaction from his work and the student will enjoy his studies more; his knowledge will be broader, it will help him in his future work, and he will have a wider choice of jobs.

I. I. Rabi says so succinctly (*6*):

> Science itself is badly in need of integration and unification. The tendency is more the other way . . . . Only the graduate student, poor beast of burden that he is, can be expected to know a little of each. As the number of physicists increases, each specialty becomes more self-sustaining and self-contained. Such Balkanization carries physics, and, indeed, every science further away from natural philosophy, which, intellectually, is the meaning and goal of science.

A broader understanding of science as a whole, beyond professional specialization, is a necessary condition for fostering the attitude toward nature, which should be the basic philosophy of a scientist. It is that attitude of intimacy with the universe, with its richness and its uniqueness, the feeling of special responsibility toward nature here on Earth, where we have power over it, constructive and destructive. The deeper understanding of nature as a whole leads to a duty on the part of the scientific community to be watchful and to warn against intentional and nonintentional misuse of science and its applications.

Another destructive element within the science community is the low esteem in which clear and understandable presentation is held. This low esteem applies to all levels. The structure and language of a scientific publication is considered unimportant. All that counts is the content; so-called "survey" articles are understandable only to experts; the writing of scientific articles or books for nonscientists is considered a secondary occupation and, apart from a few notable exceptions, is left to science writers untrained in science, some of whom are excellent interpreters. Something is wrong here. If one is deeply imbued with the importance of one's ideas, one should try to transmit them to one's fellows in the best possible terms.

In music, the interpretive artist is highly esteemed. An effective rendering of a Beethoven sonata is considered as a greater intellectual feat than the composing of a minor piece. We can learn something here: Perhaps a lucid and impressive presentation of some aspect of modern science is worth more than a piece of so-called "original" research of the type found in many Ph.D. theses, and it may require more maturity and inventiveness. Some students may derive more satisfaction from an interpretive thesis—and so may some readers.

Furthermore, the scientist helps himself by attempting seriously to explain his scientific work to a layman or even to a scientist in a different field. Usually, if one cannot explain one's work to an outsider, one has not really understood it. More concerted and systematic effort toward presentation and popularization of science would be helpful in many respects; it would provide a potent antidote to overspecialization; it would bring out clearly what is significant in current research, and it would make science a more integral part of the culture of today.

Much more could and should be done to bring the fundamental ideas nearer to the intelligent layman. Popularization of science should be one of the prime duties of a scientist. The most important instrument for spreading the spirit of basic science is education. Young people should become more familiar with the insights into the workings of nature which our age has revealed. There is more to it than the mere teaching of science. Scientific education must include active involvement in research. Students can absorb the spirit of science only if they face unsolved problems, participate in the process of analyzing facts, sift evidence, construct and test new approaches and ideas. Even at the lower levels, in elementary and high school, science activities should play an increasing role. Intelligent play involving simple natural phenomena fosters a deeper appreciation of our natural environment and transmits the joy of discovery. Margaret Mead (*7*) expressed it most impressively:

> Any subject, no matter how abstract, how inanimate, how remote from the ordinary affairs of men, remains lively and growing if taught to young children who are themselves growing by leaps and bounds, hungering and thirsting after knowledge of the world around them. To children, an understanding of the world around them is as essential as the tender loving care that, during this century, has been so exclusively emphasized in discussions of early childhood education. The language of science will then become—for everyday use—a natural language, redundant, wide in scope, deeply rooted in many kinds of human experience and many levels of human abilities.

Epilogue

Science is involved with society in many respects. There is a broad spectrum of relations—philosophic, social, and ethical—by which science influences and is influenced by society. The significance of science becomes evident in the numerous, often contradictory, aspects in which it interacts with the affairs of men.

The philosophic significance is derived from the progressively deeper and more comprehensive insight into the workings of nature. The edifice of ideas that brought about this understanding of nature was erected during the last 300 years and is one of the most sophisticated systems of thought ever constructed by man. Its great power resides in the essential simplicity of the fundamental concepts. The infinitely complicated variety of phenomena seems to emerge from a few simple, though subtle, laws of nature.

The social significance derives from the increasing ability to change our environment and the quality of life by applying the results of science. The changes have been both beneficial and detrimental, depending on the wisdom and intentions of those who carried them out. They have had deep and lasting effects on the social structure of society. The ethical significance derives from the recognition that the evolution of life and men on Earth is predicated on a most precarious equilibrium of physical conditions on this planet. From this recognition follows a human responsibility to protect and continue the great experiment of nature which required several billions of years to get under way. Science emphasizes the unity of human beings in the urge to gain rational understanding of the workings of nature, and in the task of caring for their natural environment. It brings people together in the search for deeper insights, on a front which to a large extent remains uninfluenced by the political and social divisions.

Science claims universality. All phenomena and all human experiences are supposed to fit into the context of natural laws and have found or will probably find a scientific description or explanation. However, the scientific interpretation of human experiences does

not always shed light on those aspects that are often considered most relevant. These aspects include human emotional experiences, such as feelings and value judgments. They are decisive in the realm of human decision-making. Whenever a choice is made between actions, whenever collective or personal decisions are taken, scientific reasoning can and should provide information about predictable consequences. The actual decision, however, remains outside of science, it represents a kind of reasoning which necessarily is complementary to scientific thought.

Science contains many activities of different aims and different character—the several basic sciences with all their variety of approach from cosmology to biology and the numerous applied sciences that are spreading and involving more and more aspects of human concerns. Science is like a tree in which the basic sciences make up the trunk, the older ones at the base, the newer, more esoteric ones at the top where growth into new areas takes place. The branches represent the applied activities. The lower, larger ones correspond to the applied sciences that emerged from older basic sciences; the higher, smaller ones are the outgrowth of more recent basic research. The top of the trunk, the frontier of basic research, has not yet developed any branches. Applying this picture to the physical sciences, we would locate classical physics, electrodynamics, and thermal physics at the lowest part of the trunk with broad branches representing the vast applications of these disciplines. Higher up the trunk we would put atomic physics with well-developed branches such as chemistry, materials science, electronics, and optics. Still higher we would find nuclear physics with its younger branches symbolizing radioactivity, tracer methods, geology, and astrophysical applications. At the top, without branches, so far, we would locate modern particle physics and cosmology. There was a time, only 50 years ago, when atomic physics was the branchless top.

All parts and all aspects of science belong together. Science cannot develop unless it is pursued for the sake of pure knowledge and insight. But it will not survive unless it is used intensely and wisely for the betterment of humanity and not as an instrument of domination by one group over another. There are two powerful elements in human existence: compassion and curiosity. Curiosity without compassion is inhuman; compassion without curiosity is ineffectual.

References and Notes

1. This figure is based upon an exponential increase of expenditure with a doubling time of 10 years, as it occurred during the last two decades, and a final yearly expenditure of $3 billion. The starting time is irrelevant.
2. From a contribution by H. B. G. Casimir at the Symposium on Technology and World Trade, National Bureau of Standards, U.S. Department of Commerce, 16 November 1966.
3. E. Purcell, quotation from an unpublished report to the Physics Survey Committee of the National Research Council, Washington, D.C.
4. M. Polanyi, *Personal Knowledge* (Univ. of Chicago Press, Chicago, 1958), p. 182.
5. Similar views have been expressed by T. R. Blackburn [*Science* **172**, 1003 (1971)].
6. I. I. Rabi, *Science: The Center of Culture* (World, New York, 1970), p. 92.
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National Environmental Policy Act: How Well Is It Working?

In a moment of jubilation, shortly after Congress passed the National Environmental Policy Act (NEPA), which he coauthored in 1969, Senator Henry M. Jackson acclaimed the new law as the "most important and far-reaching conservation measure ever enacted." It will be some time, of course, before anyone can fairly judge whether the law actually has lived up to Senator Jackson's description. But at the 2-year mark, NEPA has clearly established itself as one of the most controversial environmental measures of all time—one whose repercussions have rattled virtually every department and bureau of the federal government in a remarkably short time.

The law has two major features. One establishes the President's three-man Council on Environmental Quality (CEQ), which is partly responsible for encouraging the government to comply with NEPA and partly for advising the President on environmental affairs. The other feature is a broad statement of policy to the effect that government should seek to enhance the environment "by all practical means" consistent with other national policies, and that every citizen should help. What lends muscle to the lofty intentions of NEPA is an "action-forcing" provision that requires government administrators to prepare detailed statements of the environmental effects of any major action they propose, and to study all practical alternatives.

This "action" proviso is at the focal point of the controversy over NEPA and has led to efforts by some agencies to seek legislative exemptions from the law. These efforts, and the court rulings that led to them, were described in an article last week; this article deals with NEPA's more pervasive day-to-day effects on the government.

Is NEPA, in fact, producing useful results? The law's success, to a great extent, is in the eye of the beholder. Unquestionably, the law has given both community and national environmental groups a substantial new access to the courts, and, in turn, their litigation has given NEPA a forceful clout that it might never have had otherwise. The most visible offspring of this symbiotic union has been a series of federal court rulings that have dealt some stunning setbacks to major programs of the Atomic Energy Commission (AEC), the Department of the Interior, and even the Environmental Protection Agency—all of which inspires one environmental lawyer in Washington to call NEPA "the great equalizer."

Like the pistol of the same name, NEPA has also engendered a certain amount of ill-will, particularly among congressmen from districts where public works have been held up for court-ordered environmental reviews, as well as among a growing number of government administrators whose programs have been paralyzed by similar court rulings. Several observers of the new law's evolution detect a strong undercurrent of resentment toward NEPA among such mid-level officials, who often seem to regard it as less of an instrument of enforcement than as a weapon of malicious harassment.

So far, the highest government official to say so publicly is John A. Carver, Jr., a Democratic appointee to the Federal Power Commission (FPC). In a recent speech to a petroleum industry group, Carver said that "NEPA has minimal impact in any substantive way," and that, while it may be a laudable expression of policy, "its sole observable function has been that of furnishing a weapon of delay to those who would use it for that purpose."

Carver's remarks, however, obscure the fact that judicial rulings and consequent delays of pipelines, power plants, and dams have been based on what the courts found to be cursory, slanted, or otherwise inadequate environmental impact statements. Delays and the agencies' reactions to them also have tended to obscure a number of less sensational but nonetheless positive side effects of NEPA which—in the long run—may prove to be a more accurate and lasting measure of the law's worth than delays imposed by litigation.

The law and its requirement of impact statements has forced, perhaps not obviously, nearly every agency—over 40 in all—to conduct a sometimes agonizing reappraisal of the way it performs its business and the way its business affects the environment. As a direct result of NEPA, the federal government this year will spend thousands of man-hours and perhaps $20 million that it never spent before to anticipate the adverse effects of pest-control programs, military installations, highways, and numerous other major and minor public works worth billions of dollars.

All this activity has imposed an unfamiliar burden of introspection and public exposure on federal agencies, in addition to masses of new paperwork and considerable overtime labor. This process has also produced an unprecedented flood of information about the environmental effects of government activities and their underlying rationale.

Among others, Russell E. Train, the chairman of the CEQ, believes that NEPA has opened some important cracks in executive secrecy in that it forces government administrators to articulate the reasoning behind their activities—and to solicit and respond to comments from both the public and other agencies—before taking any major action.

NBS Loses Branscomb to IBM

The President's technology opportunities program, which was unveiled early this year, assigned a lead role to the National Bureau of Standards (NBS), marking what was probably the first time the bureau has starred in any program of national prominence. Lewis M. Branscomb, the man who aroused the low-profile and somewhat sleepy agency to such eminence after only 2½ years as its director, announced last week he is leaving to become vice-president and chief scientist of IBM. This decision, which Branscomb explains as "a personal opportunity for me that is not likely to come again," will deprive the Washington science scene of one of its rising and brighter stars.

IBM did not have to scour the length and breadth of the nation for its new executive. Emmanuel R. Piore, present chief scientist at IBM and a doyen of American statesmen of science, is a member of the NBS visiting committee. An atomic physicist, not a computer technologist by trade, Branscomb will direct IBM's research on a strategic rather than a tactical basis. IBM spends roughly $500 million a year on research and development, compared with a total budget of less than $50 million enjoyed by the NBS. Branscomb thus steps into a job that is ten times larger and, it is said, will roughly double his present salary of $36,000. Since becoming director of the NBS in June 1969, he has turned down at least two university presidencies and has been in the running for the presidency of Massachusetts Institute of Technology (which went to Jerome B. Wiesner) and the directorship of the National Science Foundation (assigned to H. Guyford Stever).

Branscomb, age 45, has been with the NBS for more than 20 years, serving first in its atomic physics section, and from 1961 as head of the Joint Institute for Laboratory Astrophysics, a cooperative venture between the NBS and the University of Colorado. The 2½ years since he succeeded Allen V. Astin as NBS director is too short a time to have turned around a federal agency that is itself part of a larger bureaucracy, the Department of Commerce. Branscomb has made few changes of substance, and his most notable achievement has probably been to foster a change in attitude toward the bureau and a recognition of its potential as the government's instrument for stimulating industrial technology.

Until recently, the National Science Foundation had this suddenly fashionable area all to itself with its RANN program (research applied to national needs). The new money for enhancing industrial research in this year's budget was in fact split between the National Science Foundation and the NBS, a partition that many attribute to Branscomb's powers of persuasion with White House officials, including Peter G. Peterson, who has now become Secretary of Commerce. Largely through gaining a share of the industrial technology incentives program, the new budget request for the NBS is, at $72 million, some 60 percent larger than last year's.

Branscomb's empire-building spirit has been less in evidence in consumer product testing, a field that might be expected to interest a standards bureau. The affair of the AD-X2 battery additive, which 18 years ago occasioned the firing and rehiring of the previous NBS director, has not been forgotten in the bureau. Branscomb says it would be "very unwise" for the NBS to get into consumer product testing because its sophisticated equipment can better be used in devising methodologies of testing than in assessing particular products.

Branscomb has served on several of the key advisory committees that form the backbone of the science governance system. He has been a member of the ballistic missile defense advisory committee, the president's science advisory committee (PSAC), and the defense science board. Branscomb says he will be too busy at IBM to participate in the Washington science advisory committee system. But his experience at IBM will clearly place him at no disadvantage as a candidate for the science-based posts that may become available in future.—NICHOLAS WADE

Harvard Teaching Assistants Strike

Harvard's teaching fellows, to protest a cut in their financial support, have formed a new union which has apparently succeeded in getting their support restored. However, it is too soon to tell whether the group will wither away or become a long-term force on campus.

On 28 March, some 500 union supporters picketed Harvard classes to protest a decision made by R. Victor Jones, Dean of the Graduate School of Arts and Sciences, to redirect half of Harvard's contribution to assist teaching fellows—$800,000—to academic departments' discretionary funds. The change would have affected graduate student teachers by knocking in half the tuition rebates by which, in the past, Harvard has reimbursed them on the basis of need. While not exactly a pay cut, the decision would have had an impact on approximately half of the graduate school's 2200 resident graduate students. Union spokeswoman Barbara Herman says, "this was felt to be inequitable." After the cut was made public, the Graduate Students and Teaching Fellows Union was formed and made their one-day picket of Harvard classes.

Herman estimates that the union's pickets stopped 85 percent of all Harvard teaching activities. Although the administration does not recognize the union and no negotiations were held, Jones did announce shortly after the day-long strike that the $800,000 will go to teaching fellows' tuition rebates after all. While pleased with their success, Herman says the union now plans to continue to press for recognition—either by Harvard or by the National Labor Relations Board—and will take up other issues.

The union claims to represent about 1050 graduate students, of which 500 are also teaching fellows. It has some faculty support. "After all, we were graduate students once too," commented one professor. Another, Karl W. Deutsch, professor of government, said "I am not frightened at the thought of a union. Many highly skilled people have unions." Deutsch was one of those professors who rescheduled his 28 March class rather than cross or have his students cross the union's picket lines.

The tuition rebate issue is specialized, and also appears to be resolved. But Herman claims that there is a larger issue which may help the union to last: dissatisfaction with the university's new president, Derek C. Bok, who took office only last year. Herman says that Dean Jones is Bok's "major academic appointment" in the graduate school, and that the tuition rebate cut is typical of decisions the Bok team has made. "They seem to have been making statements on the basis of financial efficiency and not heeding their educational implications." As added evidence, she cited a lowering of graduate school enrollments and a plan to have Harvard University Press publish fewer works that are purely of scholarly interest and more that will sell profitably.

If dissatisfaction with the Bok administration is widespread, the union could have fertile ground to take root permanently. One index of such dissatisfaction has come from undergraduate Garrett Epps, outgoing editor of the *Harvard Crimson*. In the editor's traditional "parting shot" editorial, Epps criticized the Bok appointees as "slick maximizers" and contrasted them unfavorably with the "zany yankees" who characterized the administration of Bok's controversial predecessor, Nathan M. Pusey. Bok, Epps wrote, makes "cosmetic concessions which divide and pacify the constituencies he must manipulate." Whether or not the student's charges are accurate, it would appear that in some quarters the new President's honeymoon is over.

More important, however, for other campuses is the success, if limited, of the union tactic. As one administration official pointed out, a whole series of events, including investigations of alleged discrimination by the Department of Health, Education, and Welfare, is changing the tone of decision-making on campus. "The universities are now in the real world of economics," he said, "and this has a whole range of implications for labor regulations. It is clearly one of the issues of the 1970's."—D.S.

Still, there is no clear evidence that government officials are using this new information to a significant extent in their day-to-day decisions. It would be excessive to say that thousands of impact statements are piling up uselessly on the desks of obdurate bureaucrats; one can in fact find instances in which NEPA studies have prompted changes in a project, not the least of which is the trans-Alaska pipeline. But, on the other hand, such examples are hard to come by, and those that do exist are often complicated by overtones of judicial duress or the threat of it. It is important to note at his point that nothing in the law gives anyone veto power over any project or decision; nor is there any language which says explicitly that an agency must *use* an impact statement once it has gone to the trouble of writing one. Environmental groups hope the courts will eventually make that interpretation of the law, but so far the courts have not.

On balance, it seems as if federal agencies are still much more intent on meeting the letter of the law than on voluntarily adopting its spirit. As Robert Cahn, a member of the CEQ, puts it, "NEPA has been a very effective tool for arousing and informing the public, but it is not yet an effective tool in the decision-making process. . . . Perhaps it's too much to expect this kind of revolutionary measure to work as fast as we'd hoped, and for agencies to cancel or modify projects as a result of it this soon."

In the past 2 years, more than 4000 environmental impact statements have poured into the CEQ's small quarters near the White House. Six employees screen them for poorly done or otherwise remarkable statements, although the CEQ tries to avoid commenting on them individually; that is the job of the various agencies and it is the council's intent to make the process as self-operable as possible.

The volume of statements is deceiving in a way, since roughly half of them are brief and rather perfunctory documents concerning small highway projects and new airport construction financed through the Department of Transportation. (DOT is the leader in numbers but not quality. The Department of Housing and Urban Development and the FPC also rank near the bottom of the quality scale. Although impact statements are generally improving in sophistication and thoroughness, many, CEQ sources say, still amount to little more than post facto justifications of decisions already made.)

Each month's accumulation of statements is listed and summarized in a publication from the CEQ, the *102 Monitor*, named after section 102 of NEPA which requires them. The latest selection begins with a 48-page discussion from the Department of Agriculture on its annual fire ant spraying program and ends with a 13-page document from the DOT concerning the repaving of 4.4 miles of roadway in Lafayette County, Wisconsin. Although most of the 200 statements in between run no more than 100 pages, there are exceptions: The final impact statement on the trans-Alaska pipeline, released late last month, fills nine volumes and weighs 18 pounds. Interior Secretary Rogers C. B. Morton describes this weighty compilation as the most thorough examination of environmental effects that "any work of man has ever had." In any case it is one of the longest and, from all appearances, a great improvement over the first try—a 200-page paper so poor that even the Army Corps of Engineers found itself complaining about it last year.

As might be expected, such a massive new occupation as the writing of impact statements has brought with it some difficult learning experiences and even some organizational changes in a number of departments and bureaus. Each of more than 40 agencies has had to compose complex guidelines for writing its statements, and then has had to train hundreds of professional and clerical employees to use the guidelines. Some agencies, like the AEC, have had to start from scratch a second time, after a federal court ruling, in effect, invalidated the first set.

Throughout the Executive Branch the advent of NEPA has also fostered the appearance of new offices of environmental affairs and improved the fortunes of old ones, as agency heads have come to recognize that a deftly written impact statement can make all the difference between smooth sailing for a program and complete paralysis. Now, hardly a federal agency is without an environmental office, and those that lack one have not escaped NEPA's grasp entirely. The Securities and Exchange Commission, for example, requires corporate stock prospectuses to disclose a company's expenditures for meeting pollution control regulations and to own up to environmental lawsuits hanging over it.

Rough estimates of what complying with NEPA has cost the government in manpower and dollars are impressive but nonetheless small compared with overall budgets and employment. The AEC, for example, has 200 employees doing nothing but writing its own impact statements and reviewing scores of them from other agencies. (Any given statement generates anywhere from 5 to 35 sets of comments from sister agencies.) Atomic Energy Commission chairman James R. Schlesinger estimates that this effort will cost the commission about $6 million in fiscal 1973, or less than 1 percent of the AEC budget.

The Agriculture Department estimates that impact studies and statements for the Forest Service, pesticide programs, flood-control projects, and a wide assortment of other projects will cost $2 million this year. The Interior Department predicts an outlay of $8 million and the diversion of 400 to 600 man-years to NEPA activities. An added expense for the Interior Department is a new computer system to keep track of hundreds of NEPA documents circulating through its Washington headquarters and field offices scattered across the country.

There is a widespread feeling in Washington, and not just among environmentalists, that all this prodigious labor must have had a salutory effect on the federal bureaucracy, that it has been or will be something of a consciousness-raising experience. As Russell Train told a recent Senate hearing, the result of the mandatory analyses and the interagency consultations "can only be more informed decision-making." Despite some complaints about the assiduousness with which the courts have been enforcing NEPA, Interior Secretary Morton and AEC Chairman Schlesinger have voiced similar thoughts. Roger Cramton, the chairman of an

Court Affirms AEC Authority

The Supreme Court on 3 April said no to states that want to set radioactive effluent standards for nuclear power plants that are more restrictive than those of the Atomic Energy Commission (AEC).

The seven to two decision culminated a suit brought by the Northern States Power Company of Minnesota. The company sought to invalidate state regulations that set allowable radioactive emissions at about 2 percent of those permitted by the AEC. The brief, unsigned order affirmed the argument of lower courts that it was the intention of Congress to make power plant radiation standards the "exclusive responsibility" of the AEC.

Several states have been inducing utilities to conform with standards that go beyond those of the AEC, but Minnesota is the only one in which a company has brought the matter to court.

The AEC announced last June that it planned to lower the ceiling for radioactive emissions to about 1 percent of what is presently allowed, which would bring them roughly in conformity with the tighter state standards. Nonetheless, many state officials are upset by the court decision. A spokesman for the Minnesota Pollution Control Agency said that the state and the AEC still differ over permissible emissions for various isotopes. Further, he says, the court decision runs against the state's approach, which is to work with each company individually to bring emissions down to the lowest practicable level.

A lawyer for Pennsylvania's Office of Radiological Health, which also has its own emission standards for nuclear power plants, says that the decision has seriously undercut states' potential to exert pressure on the AEC to improve its standards.

Power companies have generally shown a willingness to cooperate with state guidelines while the authority of states in this area awaited clarification. Continued voluntary compliance is in doubt now that states have no legal recourse.

Several members of Congress have introduced bills that would give states clear authority to lay on restrictions for radioactive emissions above and beyond those of the AEC. These are now sitting in the Joint Committee on Atomic Energy, and there is no evidence that the recent Supreme Court decision will hasten action.—C.H.

obscure but elite group called the Administrative Conference of the United States, an efficiency-promoting arm of the Executive Branch, predicts that the initial anger and resentment that mid-level bureaucrats have felt toward NEPA will give way to "an institutional viewpoint more sympathetic to environmental, as opposed to purely programmatic, values."

"Admittedly this is largely a prediction rather than an accomplished fact," Cramton adds; and he goes on to warn that it's entirely possible that NEPA may give rise to a new form of "bureaucratic gamesmanship," in which an agency's expertise is used to shape impact reports to fit preconceived decisions rather than the other way around. Representative John Dingell (D–Mich.) the other coauthor of NEPA, worries about this possibility too. The law's requirements, he said in a recent speech, are often complied with grudgingly, "behind a facade of false enthusiasm," and a risk exists that the law may do no more than spawn a race of adept memo artists "totally lacking in vision and concerned only with robotlike compliance. . . ."

Such fears are not without substance. In actuality, the main objective of most agencies appears to be one of writing defensible impact statements while minimizing changes and consequent delays in their work—most of which was under way when NEPA became law. There is some feeling at the CEQ that the machinery for producing NEPA reports, while becoming larger and more adept, has not begun to mesh satisfactorily with the machinery for making decisions. Added support for this view comes from an investigation by the Government Accounting Office of seven agencies' activities under NEPA. The study, made at Representative Dingell's request, has concentrated almost exclusively on procedural details for preparing statements, but some of the GAO investigators nevertheless came away with the personal impression that the law's identifiable effects on agency decisions have been less than monumental. "NEPA is more than just a papermill," one GAO man said, "but one concern is that impact studies are not being done soon enough to really affect the decision process. Agencies tend to wait until after it's decided that a power plant or a highway is needed, and after the site is selected, before thinking about the impact."

The CEQ has tried to compile a list of exemplary accomplishments under NEPA, but so far the list is conspicuously short. For one, the CEQ justifiably credits itself with convincing President Nixon to kill the Cross-Florida barge canal, and after all, NEPA created the council, which the President initially had thought unnecessary. As another example, the Interior Department says that NEPA studies have led it to tighten design requirements for the trans-Alaska pipeline, and that if the line is built it will be less detrimental to the Alaskan tundra than it might have been before.

Further inquiries reveal some evidence that NEPA has forced federal highway authorities to pay more attention to known prehistoric Indian sites rather than blithely paving them over because they were not officially listed in the Federal Register. The Interior Department's Bureau of Reclamation can also proudly claim that it will dig a borrow pit for gravel behind a small earthen dam in southeastern Idaho as a result of NEPA studies, rather than in front, where the pit would remain as a visible scar on the landscape for decades. (This has by no means become standard practice, however. Nor has the need for the dam itself been seriously questioned.) Further, in the Department of Agriculture, the annual acreage to be sprayed for gypsy moths this year has been sharply reduced, partly, but only partly, as a result of reappraisals forced by NEPA.

"This is a very hard thing to document," Train concludes. The problem, he explains, is that one never hears about the decisions that aren't made or about projects that were modified early in the game as a result of NEPA studies. Precisely why is unclear. It may be that government administrators are reluctant to admit where they had gone astray and that a nettlesome law has shown them the light. To some observers however, the notion of unsung environmental heroes in the depths of federal agencies seems implausible. At any event, modesty of this sort is an unfamiliar virtue.

Certainly NEPA has had some beneficial spinoff that weighs heavily against its drawbacks. The public exposure it provides to formerly closed administrative procedures represents an important new restraint on executive arrogance. In creating the CEQ, the law placed a vigorous, though not always successful, advocate for environmental interests within the sanctum of the White House.

But before the law goes much further toward lifting the scales from the eyes of the builders and diggers in the federal government, the courts will probably have to take a second bold step in reading NEPA's lofty language —and require that agency administrators make a reasonable showing that their decisions do in fact take account of all the new environmental information that it generates.

—ROBERT GILLETTE

OECD: Report Sees Closer Links between Research, Social Objectives

For its industrialized member countries, the Organization for Economic Cooperation and Development (OECD)* has proved to be the most useful of international forums for consultation and mutual criticism on economic matters. At the time of the flap over the technology gap, for example, the organization provided a meeting ground for OECD science ministers and much of the analysis that enabled them to put the issues into perspective. Since OECD was created as a spinoff of the Marshall Plan, it has treated education and scientific research as essential social and economic factors and, through a competent secretariat, has generated solid data and some enterprising studies in these areas. OECD's series of reviews of national science policy, including an extramural one on the Soviet Union, has contributed a good deal to defining the goals and describing the mechanisms of science policy. And this month, OECD is scheduled to take the science policy reviews a step further with publication of a comparative study of the organization and financing of fundamental research in France, Germany, and the United Kingdom.

*OECD member countries are Austria, Belgium, Canada, Denmark, Finland, France, the Federal Republic of Germany, Australia, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States.

The idea for the study was germinated during discussions on the technology gap, but the project was carried through at a time when concern in Europe and the United States had shifted to a quest for ways to link science and technology more directly to the accomplishment of social and economic objectives. And a major premise of the report is that support of fundamental research is increasingly based on evidence that such research will contribute to achieving these objectives. Or as one author of the report told *Science*, "You can no longer speak of research without taking into account social demand."

The survey is actually part 1 of a scheduled three-part effort. Part 2 is to deal with smaller European countries, and part 3 to compare the situation in Europe with that in Canada, Japan, and the United States.

The first report is really an examination of the web of relationships connecting industry, government, and the universities in scientific matters. As a comparative study, it bounces around, sometimes disconcertingly, from industry to university to government and from country to country. Its chief virtue is that its authors, members of a multidisciplinary team headed by J. J. Salomon of the OECD directorate for scientific affairs, give the impression of being in direct touch with their sources of information, of writing with less attention to diplomatic politesse than is often the case in the reports of international organizations, and of being willing to question the assumptions that govern science policy. If one thing marks the report as a product of the 1970's rather than of the 1960's it is that the authors have concluded that the major obstacles to fundamental research in the countries under study are structural rather than financial.

The report is up-to-date in the sense that it takes into account "dislocations" in the scientific community, which are making it increasingly difficult for able young scientists to find employment either in universities or in research jobs outside university walls. At the same time, the report finds that, despite new conditions, research institutions, particularly universities, have not changed significantly in character. European universities have not reached the "advanced stage of scientific col-

Keeping an Eye on SESPA

Boston. The American Chemical Society braced itself for protest demonstrations at its national meeting in Boston this week after an unexpected phone call from the Federal Bureau of Investigation. The FBI's Boston office warned the ACS to expect disruptions at a session last Sunday evening, then helpfully supplied the names of half a dozen persons who might be expected to lead them.

As it turned out, the trouble failed to materialize at the predicted hour, but ACS officials indicated that they were nonetheless grateful for the FBI's help. Along the way, it became evident that the FBI follows in some detail the activities of Scientists and Engineers for Social and Political Action (SESPA), a loosely knit group who publish a magazine of radical bent called *Science for the People*, and who are perhaps best known for demonstrations that they have staged at AAAS meetings. A SESPA spokesman interviewed by *Science* said he was surprised and dismayed that the FBI should be interested in the group, and he said the FBI's apparent surveillance amounted to a form of intimidation. Neither the Justice Department nor FBI offices in Boston and Washington would comment.

The chemical society's national meetings manager, A. T. Winstead, at first denied any knowledge of possible disruptions, then conceded that the FBI had indeed called. "We really wanted to keep this hushed up," he said, adding that the ACS had quickly arranged for a number of uniformed and plainclothes security guards to hover around the meeting at the Sheraton Boston Hotel. "We'd been expecting trouble for the past several years, and we were prepared," Winstead said. "But this year we hadn't bothered until the last minute."

What changed the minds of ACS officials was a telephone call last Friday noon from Bernard McCabe, a supervisor in the Boston FBI office, to Arnet L. Powell, a former chairman of the society's northeast section. Powell said agent McCabe told him the Boston police had been advised that SESPA might "march on" the ACS meeting, and would he pass the word along? Powell, a chemist at the Office of Naval Research, emphasized that his only previous contact with the FBI was in the course of routine security clearance checks.

Some weeks before the Boston meeting, SESPA members asked the ACS for permission to set up a table to distribute literature and for the use of a small meeting room. The ACS board of directors turned down the room request but allowed the table. Last Sunday afternoon, several neatly dressed young men and women attending the table in a bustling lobby said Winstead apparently had a list of names of SESPA people that went well beyond any mentioned in correspondence with the ACS. "I wondered how he knew so many names," one graduate student from M.I.T. said. Others in the group seemed both surprised and a little awed that the FBI should be interested in them.

Joe Richmond, who said he is a postdoctoral chemist at Harvard, and who was among those named on the FBI list, conceded that SESPA members had talked about plastering posters around the ACS meeting and staging a guerilla theater skit during one session, but that too few members had shown up on Sunday to make this possible. Richmond said SESPA's objective was not to disrupt the meeting but to draw attention to what it felt were urgent issues of ethics and unemployment facing chemists and which the ACS leadership was ignoring.

In general, the SESPA members who did show up at the ACS meeting Sunday seemed less bellicose than many who have appeared at AAAS meetings. It is worth noting that, since SESPA tries hard not to develop a strong central leadership, its character may be expected to change from one week to the next and from one place to another. In Boston this week, Joe Richmond said "We aren't trying to alienate. We are genuinely trying to reach out and communicate." Nevertheless, the ACS is on its guard, thanks to the FBI.—R.G.

laboration" achieved in the United States, the report says. Putting it another way, the report says European universities lack the "entrepreneurial spirit" of their American counterparts.

In all three countries under study, the major share of fundamental research is carried out through a dual system—the universities plus what the report terms a "peripheral" system. In Britain this peripheral system is made up primarily of government laboratories, in which scientists make careers as researchers outside the universities. In France, the Centre National de la Recherche Scientifique (CNRS) and other government agencies support separate laboratories and individuals on a scale that matches the university research apparatus. In Germany, the Max Planck Institutes and other peripheral research institutions provide the alternative to university research.

The report asserts that university expansion and reform, in the three countries, while substantial, has had little operational effect on research. In fact, the drive toward departmentalization in France and Germany may carry the danger of creating large, self-contained units, based on a single discipline, which get little stimulus to be outward looking and are resistant to interdisciplinary work.

The report's authors see little mitigation of the Old World lack of mobility among scientists. Only in Germany is there evidence of willingness to move from university to university and from university to industry.

There are, of course, other national patterns reflecting political and administrative habits and histories. The French system for science is the most highly centralized of the three, with budgeting and policy-making powers concentrated in a top-level interministerial body. The British operate the most pluralistic system, with research funds coming from a number of government agencies. The British system is influenced by the so-called Haldane doctrine, which calls for a separation of authority over fundamental and applied research, with applied research funded through the "technical" ministries and fundamental research support allocated through research councils dominated by nongovernment scientists. The report describes the German system as the British system "adjusted in the light of federalism," which means that the central government and the Land, or state, governments join to support research institutions in a variety of financing patterns.

Despite such national differences, the report identifies major problems common to all three countries. One of these is the "aging" process in laboratories operated by the government.

As the authors put it, "The question obviously does not arise in recently established and still expanding agencies for which the difficulty is still rather

Patents: To Combine or Not to Combine

In New York on 29 March the antitrust division of the U.S. Department of Justice filed a suit against 20 of the nation's biggest aircraft manufacturers, alleging that for 44 years they illegally agreed to cross-license each other's patents on airplane parts, to the exclusion of other companies. The effects have been "restricting and suppressing competition . . . in the research, manufacture, and sale of airplanes" and "hindering and delaying the research and development of patentable inventions for airplanes." Government economists say the agreement has effectively discouraged innovation within the industry.

The list of 20 defendants includes the granddaddies of the U.S. aircraft industry, many of whom are the country's largest defense and space contractors: Boeing Co., Curtiss-Wright Corp., Fairchild Hiller Corp., General Dynamics Corp., Grumman Aircraft Engineering Corp., Ling-Temco-Vought, Inc., Lockheed Aircraft Corp., Martin Marietta Corp., McDonnell Douglas Corp., North American Rockwell Corp., and United Aircraft Corp. Named also is the organization formed in 1928 to administer the agreement, Manufacturers Aircraft Association, Inc. (MAA). The suit calls for the termination of the agreement and for MAA's dissolution.

Ironically, the suit was filed one week after the President's technology message was issued, which in one section stressed the desirability of having firms combine on R & D efforts which are too costly or risky to attempt singly. "Especially in highly fragmented industries," the message said, "formal or informal combinations of firms provide one means for hurdling these barriers. . . . In general, combinations which lead to an improved allocation of the resources of the nation are normally permissible, but actions which lead to excessive market power for any single group are not." In an "on the other hand" passage, the technology message rules undesirable "joint efforts among leading firms in highly concentrated industries." This view is a page borrowed from the book of the January *Economic Report of the President*, which says, in its R & D section, that consortia among private firms are desirable in highly fragmented industries. But "joint efforts" among leading firms in "highly concentrated industries" are undesirable. Evidently the Justice Department has now decided that the airplane manufacturers' agreement falls in the latter category.

The problem is one of relativity. What agreements are considered "desirable" is liable to shift from time to time. For example, the aircraft companies' agreement on patents, says one MAA spokesman, was first drawn up in 1917, as a direct result of U.S. preparations to enter World War I. Then, there was a need to create a fleet of 25,000 airplanes from an aircraft industry that was, at the most, nascent. Not only did the government, including the then Assistant Secretary of the Navy, Franklin D. Roosevelt, encourage the companies to get together and utilize each other's patents at that time, but the agreement has been reviewed by Justice since then and found legal. Now, the Justice Department has decided the agreement violates the 1890 Sherman antitrust act. Hence, while the suit may have little immediate impact on aerospace R & D, it does indicate which way the winds are now blowing in Washington on combinations of firms in "highly concentrated" industries.

—DEBORAH SHAPLEY

to find [than] to recruit a sufficient number of competent scientists. On the other hand, the problem is becoming critical for agencies which are obliged to curb their growth, and in some cases even reduce their staff. Even if this can be done relatively painlessly through the mechanism of retirement, this method is inadequate and the recruitment of young scientists is usually blocked. This blockage is reflected in a very substantial rise in the average age (sometimes more than one year per year), and there is clearly no more certain way of devitalizing these bodies and transforming them into deadweights."

The report puts the problem in a broader context by describing what amounts to a life cycle for the government laboratories. They are established in the first place to achieve specific results rapidly, often in new fields of research such as nuclear energy or space. As these objectives are achieved—or not achieved—there is a tendency for research aims to blur and for the research program to become diversified. Meanwhile, industry and universities have often moved into the laboratory's original field of research. In most cases, fundamental research has been an integral part of the laboratory's activities from the start, but, as time passes, the proportion of fundamental research tends to increase. And, according to the authors, " 'fundamentalization' is often a symptom of the aging of research institutions."

In part, this phenomenon is related to low mobility among European scientists. The authors suggest that the "movement toward job security—systematically sought, moreover, by scientists' unions—may very well transform the agencies in the government sectors into havens for second-rate scientists who can be assured of making a career there, which they might well find difficult to do in more competitive sectors."

This phenomenon, of course, has been observed in the United States, and the report quotes Oak Ridge's Alvin M. Weinberg, who, so to speak, wrote the book on the subject, in describing the tendency to "transfer from mission to discipline."

What to do about this the report leaves rather open, but it leans toward what it identifies as the Weinberg position. That is, government laboratories should be assigned new tasks contributing to the solution of national problems in the way already begun at Oak Ridge and, for that matter, at Britain's Atomic Energy Authority establishment at Harwell.

The report's final section on fundamental research and technological applications is sketchier than the other sections on the organization and financing of research in universities and government agencies. This is no doubt partially attributable to the shortcomings noted by the authors in the available "global data." They quite reasonably question the value of using quantitative data in addressing what is essentially a qualitative problem. The authors, therefore, have concentrated in this section mainly on the links between the university and industry.

Despite the incompleteness of data and the fact that the definition of fundamental research is even more elusive in industry than elsewhere, the report does make some generalizations. The proportion of R & D funds devoted to basic research in particular industries seems to be roughly similar in the three countries studied. It also appears clear that chemical and allied industries—petrochemicals and pharmaceuticals—spend a much higher proportion of R & D funds on basic research than does any other industry, with the electrical-electronics industry not too far behind.

Some of the more interesting observations in the study were based on visits to science-based firms in the three countries. Again, national patterns emerge. The most satisfactory interaction between industry and research institutions in other sectors seems to be maintained in Germany. It is worth noting that the most important contacts seem to be with the peripheral system, primarily the Max Planck Institutes, rather than with the universities. The Germans encourage industry-university links in a variety of formal and informal ways—for example, through scientific societies and seminars organized by industry. German scientists in industry are more likely to teach part-time in universities than their French or British colleagues are, and German professors are more likely to do industrial consulting. German industry also does considerably more than French or British industry in the way of supporting graduate students and funding contract research in universities.

Attitudes that permeate the universities and secondary schools and the social structures of the three countries obviously help to explain the differences. And the report's authors suggest that an important external factor promoting industry-university links in Germany was the relatively unfavorable competitive position of Germany during the 19th-century period of industrialization. Like Switzerland and the Netherlands, Germany was faced with finding markets abroad, without having the colonial outlets Britain and France commanded. This external pressure helped bring German science and industry together, and it gives Germany an advantage in the present situation.

The situation today, as the report describes it, is one in which "a period of unprecedented growth in the resources allocated to research and development has been succeeded by a period of questioning and uncertainty."

The survey team's analysis, and the basic argument of the report, is set forth in this excerpt from the introduction:

> Neither the rate of growth in the resources allocated to research activities, nor the obejctives on which these resources have been concentrated for more than twenty-five years past, can be regarded as a permanent feature. On the contrary, the period which is now opening seems likely to be characterized by great uncertainties as to the ways and means of progress—or possibly of regression—of resources and the whole nature of new research programmes. Now that government concern is tending to shift away from vast technological programmes linked with defence and prestige, fundamental research programmes, too, are the subject of reappraisal. This change of priorities does not mean that less fundamental research will be needed to satisfy the demands of society, but rather that research will be required to respond more closely to the imperatives of selectivity dictated by the social, political, and industrial context. In particular, the question will arise of determining the proportion of fundamental research which should be "oriented" towards the sectors of society which call for a stronger component of technical innovation (health services, urban public transport, housing, protection of the environment, and so forth).

Perhaps the chief significance of the survey is that it marks the end of a distinct phase for fundamental research and for science policy. The OECD view has become an influential, almost official view that generally reflects, or will be reflected in, the science policy of member nations. This latest comparative study is, in a way, an extended epitaph for what the report at one point calls the "golden" era of fundamental research.—JOHN WALSH

Book Reviews

Aroused Consciences

Harvest of Death. Chemical Warfare in Vietnam and Cambodia. J. B. NEILANDS, GORDON H. ORIANS, E. W. PFEIFFER, ALJE VENNEMA, and ARTHUR H. WESTING. Free Press, New York, 1972. xvi, 304 pp., illus. $10.

Since 1961, United States armed forces have used more than 100 million pounds of assorted herbicides to defoliate forests and kill crops in more than 6 million acres in Vietnam, an area roughly equivalent in size to the state of Massachusetts. We have also used more than 14 million pounds of so-called riot-control gases; one of these, Agent CS (*o*-chlorobenzalmalononitrile), pumped into underground bunkers, has undoubtedly caused the deaths of some people, although it is alleged to be nontoxic. In addition, when used as a prelude to carpet bombing by B52's, CS bombs have probably caused the death of Vietnamese flushed from underground bunkers, who might have survived the bombing had they remained underground.

The antiplant chemical warfare agents are alleged to have seriously affected about 10 percent of the agricultural lands of South Vietnam, one-third of the forested lands, and almost half of the extensive mangrove communities lining the estuaries. Possible side effects of these operations have been several kinds of ecological havoc including increased nutrient runoff from areas cleared of vegetation, increased soil erosion, invasion of forest areas by noxious weeds such as bamboos and Imperata grass, dislocations of animal and fish populations, induration of lateritic soils which have been deprived of organic matter and exposed to the baking action of the sun, and possible spread of diseases like bubonic plague due to migration of wild rodents toward urban areas. Superimposed upon all this is the possibility that serious malformations and stillbirths may have been caused in developing embryos of pregnant Vietnamese women who consumed as little as two to three liters of water per day after a usual spray of 25 pounds per acre of mixed 2,4-D and 2,4,5-T herbicides (Agent Orange). It has been conclusively shown that at least some of the Agent Orange used in Vietnam was contaminated with 2,3,7,8-tetrachloro-*p*-dibenzodioxin, a potent teratogen effective at a concentration of about 0.01 part per billion.

In a war already marked by Mylai and similar incidents, by the burning of entire villages and the enforced evacuation of inhabitants to relocation centers, and by the "protective reaction strikes" in which, whether by design or not, churches, schools, hospitals, and dwellings are hit, why should we be disturbed by the use of chemicals that nauseate or kill a few additional people and devastate a few million acres? How can one weep for a tree when there are few tears for the killed, the wounded, the uprooted and impoverished victims of the war? One of the answers seems to be that our massive use of chemical warfare agents adds a new dimension to the escalating horror of modern war; no nation besides the United States has used chemical warfare massively since World War I.

It is estimated that in World War I more than 125,000 tons of chlorine, phosgene, and mustard gas were used in battle; as a result, there were more than 1,300,000 casualties, including more than 100,000 killed. In World War II, despite a whole new armamentarium of weapons, not a single casualty was listed as due to chemicals. Why the difference? One reason, say many, is the Geneva Protocol of 1925, inspired and written but never ratified by the United States. This protocol has now been ratified by 84 nations, and of the major powers only the United States is not a signatory. This is an accident of history; ratification by the Senate was proposed at a time when a spirit of isolation and opposition to Wilsonian doctrines was growing in the United States. That spirit, plus the opposition by the chemical industry and other branches of the then military industrial complex, prevented favorable Senate action. The issue has remained dead until the present administration. Late in 1969, Richard Nixon proposed that the Senate reconsider ratification of the protocol, which forbids the use in war of "asphyxiating, poisonous or other gases, and of all analogous liquids, materials or devices." But the President, while asking the Senate for ratification, attached an "understanding" that herbicides and riot control gases were not included within the list of items proscribed. In a vote taken shortly after at the United Nations, 80 nations opposed this view and only three, including the United States, supported it. Our only allies in this losing fight were Australia and Portugal; the latter is currently using herbicides and gases against revolutionaries in Angola. The Senate Foreign Relations Committee understandably balked at approving ratification under terms which would invite others to make similar reservations and thus, in effect, undercut the treaty. It now seems that there is no hope of our ratifying the protocol while the war in Vietnam is going on.

Although the massive use of herbicides sprayed from fixed-wing aircraft has apparently been terminated in Indochina and the practice is now restricted to helicopter-based operations around the perimeters of base camps and along certain roadsides and waterways, the use of CS gas still continues, and the military seems to want to keep its options in chemical warfare open for the future. When one notes that the United States is a party to a United Nations Resolution of 1966 which calls for observance of the provisions of the Geneva Protocol of 1925, one can understand to what extent this massive chemical warfare in Vietnam has isolated and damaged the United States in the world community. It also explains why the issue of chemical warfare in Indochina has served to politicize previously uninvolved scientists and organizations.

The authors of this book are respectively a biochemist, two zoologists, a medical doctor, and a botanist whose consciences have been outraged by our use of chemical warfare weapons in Indochina. Indeed, all of them reveal their understanding of a fact of which awareness has been growing slowly in all of America, that the bulk of the people against whom we are fighting in Indochina are united and determined to continue a struggle which for most of them began more than a generation ago and has proceeded uninterruptedly against Japanese, French, and now American invaders. With our superior technology and especially with our command of the air, we can go far toward "smashing them back into the stone age," as General Curtis LeMay is quoted as having advocated, but we can do so only at the expense of committing ourselves to a near genocidal policy of exterminating the Vietnamese as a people. By and large, we have decided that this is too great a price to pay, even for "containing communism." Accordingly, we have steered our policy between ending the war immediately ("surrendering to communism") and wreaking such destruction on the Vietnamese that the conscience of the world would be even more aroused than it has been recently. During my visit to North Vietnam in 1971, I saw both massive destruction caused by our bombs and an apparently unquenchable determination on the part of the North Vietnamese to continue the struggle. It was enough to convince me that the conflict must not and cannot be terminated by military victory, but only by negotiation, and that the time for negotiation is now, rather than later, when additional bloodshed and destruction will have made the situation even more desperate.

I know four of the five authors personally, and I think it is fair to say that all of them share the view of the war stated above; it is therefore not surprising that they decry our chemical warfare operations. Clearly if one accepts the Indochina war as a necessary operation, then one is not apt to be so bothered by U.S. transgressions against international law and by our use of chemical weaponry. There seems to be no neutral ground.

The book consists of four chapters. The first, by Neilands, documents the use of gas warfare in Vietnam; the second, by Vennema, is a brief treatment of medical effects of antipersonnel gases; the third, by Pfeiffer and Orians, chronicles the military uses of herbicides in Vietnam; and the fourth, by Westing, deals with herbicidal damage to Cambodia. The chapters are followed by several appendices, including documents such as the Geneva Protocol of 1925, a list of properties of toxic agents used in Vietnam, statements by President Nixon, Dean Rusk as Secretary of State, and the editor of *Chemical and Engineering News*, and finally a discursive review of chemical warfare by the Legislative Reference Service of the Library of Congress and an article by Philip Boffey in *Science* (**171**, 43 [8 Jan. 1971]) reviewing the work of the Herbicide Assessment Commission of the AAAS. The chapters are different in length and style. Neilands is personal, specific, opinionated, hard-hitting, frequently biochemically sophisticated, and bolstered by 341 references. Vennema is general, gentle, compassionate, brief, and without references. Pfeiffer, Orians, and Westing tend to be more objective and less passionate than Neilands, but the vigor of their arguments and occasionally their prejudices shine through. Despite the unevenness of the treatment, this book can serve better than any other to document how the aroused consciences of only a few individuals have had a major effect on the course of recent history.

It is to me a sad and sobering fact to recognize that, by and large, the American scientific community has been uninterested in its own complicity in the chemical warfare operations in Vietnam, or if interested has been unwilling to act, either from timidity, lack of involvement, or from approval of U.S. policies. In 1966, when I appeared before a business meeting of the American Society of Plant Physiologists (of which I had been president a few years earlier) with a letter addressed to President Johnson asking for clarification of his policy concerning the uses of herbicides in Vietnam, I was met by a refusal of the executive committee even to schedule the item on the agenda for the open business meeting. When I arose to present the issue from the floor, I was able to get 12 additional signatures, enough to send the letter as a petition to President Johnson. This letter elicited a reply from an undersecretary of state, spelling out clearly that we were, in fact, using herbicides to kill crops and defoliate forests. At about the same time, John Edsall and Matthew Meselson of Harvard, acting as leaders of a petition campaign initiated by Milton Leitenberg, then on the staff of *Scientist and Citizen*, got 5000 scientists to sign an anti-chemical-warfare petition, which was presented to the President. Receipt of the document was acknowledged, but no reply was ever received from the White House. Meselson went on to become head of the Herbicide Assessment Commission of the AAAS, in which capacity, together with Westing and others, he conducted investigations, partly summarized in Boffey's article in the appendix of this book, which have not yet been published. In the meantime, the National Academy of Sciences has picked up the ball, and under a grant from the Department of Defense (!) is conducting an additional survey. Thus, of all the major scientific organizations in the United States, only the AAAS has taken timely action and that only after determined prodding by Pfeiffer and a few other interested individuals.

Despite the opinionated stance of several of the authors, scientists of all persuasions will find something of value in this book. There is much authentic factual information, although occasionally the wish is father to the thought. I noted several inaccuracies, including Pfeiffer's assigning to me credit for the unearthing of information about 2,4,5-T which more properly belongs to Meselson. There are biased statements and sometimes the authors openly admit their biases. The scientific reader will be able to pick his way clearly through the melange of facts and opinions, since, in general, each is clearly demarcated. At the moment this book is the best collection of information on chemical warfare in Vietnam extant. It will serve as a primary standard, at least until such time as the Herbicide Assessment Commission of the AAAS makes its final report.

At a conference on War Crimes and the American Conscience held in Washington in 1970, I said, "After the end of World War II, and as a result of the Nuremberg trials, we justly condemned the willful destruction of an entire people and its culture, calling this crime against humanity *genocide*. It seems to me that the willful and permanent destruction of an environment in which a people can live in a manner of their own choosing ought similarly to be considered a crime against humanity, to be designated by the term *ecocide*." If this view is correct, then the book under review is a document of a kind of Mylai perpetrated against the Indochinese countryside. As such, it is required reading for scientists with a

social conscience, and will be useful, in addition, for the many courses now arising in response to the students' desire to consider the social relevance of the findings of biology.

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Quantitative Approach

Statistical Ecology. Vol. 1, Spatial Patterns and Statistical Distributions. A symposium, New Haven, Conn., Aug. 1969. G. P. PATIL, E. C. PIELOU, and W. E. WATERS, Eds. Pennsylvania State University Press, University Park, 1971. xxviii, 582 pp., illus. $14.50. Penn State Statistics Series.

This is the first of three volumes reporting the papers and discussions at a symposium held at Yale University in 1969. Two subsequent volumes are to deal with "Sampling and Modeling Biological Populations and Population Dynamics" and with "Many Species Populations, Ecosystems and Systems Analysis." Twenty-three specialized papers and some general addresses are featured in the current volume. The application of statistical and mathematical techniques in ecology has rapidly proliferated during recent years, and one of the editors (Pielou) is the author of a successful introductory text. Thus ecologists have generally accepted a quantitative approach. Yet this volume will leave many ecologists, even those with statistical proclivities, seriously perplexed. If this volume faithfully reflects the progress and achievements of statistical ecology, the direction of this science would seem misguided. At least 11 of the papers deal with the properties of various statistical distributions that *might* be of interest to ecologists. Yet the relevance of these distributions to real biological data and the biological significance of their occurrence are not discussed, biological keywords in the titles of articles notwithstanding. Some of these papers will be of interest to statistically minded ecologists, who will have to dig hard to extract for themselves kernels of material useful for their work. Other contributions clearly belong to the statistical literature. The fact that empirical data in ecology often do not permit decisions among alternative distributions is brought out in the discussion. Whether this will inhibit the generation of further distributions in the future is doubtful. The multiplicity of biological interpretations of given distributions is taken up in a paper by Hairston, Hill, and Ritte in this volume.

At least two important contributions to statistical ecology should be singled out. Morisita develops an index of environmental density which is likely to be taken up by ecologists, as were his earlier contributions, and Iwao and Kuno undertake an interesting analysis of aggregation patterns in biological populations and their implications for various theories of population dynamics. There are other papers of specialized interest which will be read with profit by ecologists of various persuasions.

Users of this volume will be seriously impeded in their ability to locate desired information by the editors' omission of any kind of index and by the publisher's unfortunate decision to employ uniform running heads for the entire volume, yielding a Shannon-Weaver diversity index of zero as one thumbs through the pages.

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Neurochemistry

Recent Advances in Adrenergic Mechanisms. BUDH DEV BHAGAT. Thomas, Springfield, Ill., 1971. x, 134 pp., illus. $13.75.

In this book Bhagat provides an introduction to the concepts of the biochemistry and pharmacology of the sympathetic nervous system. It may well serve the needs of many students, medical scientists, or practicing physicians with an inquiring interest in the field, who must have difficulty in finding a place to begin reading the accumulation of sophisticated and complete reviews, symposia, and monographs dealing with catecholamines and related subjects.

A concise account of any large and rapidly advancing field must necessarily suffer from simplifications, omissions, and personal bias. Bhagat has freely acknowledged and accepted these dangers in his attempt to present clearly and simply an account of adrenergic mechanisms. The result, although a somewhat personal view of the field, does bring to the reader a fair coverage of the major facts and concepts. In the interest of brevity, conclusions are stated with minimal attention to the data from which they were derived. Bhagat has effectively used schematic representation to explain the complex interactions of drugs with the mechanisms for synthesis, storage, release, and action of norepinephrine. The only original data presented are the author's own work, six smoked-drum tracings of cat blood pressure and nictitating membrane contraction; and as might be expected of any active investigator, the citations are skewed toward his own contributions to this field. In some of the references, abstracts rather than the full published work are cited.

It would be quite easy to suggest how this book might have been enlarged, but perhaps only at the expense of the author's objectives. There is little or no discussion of the isotopic or biochemical methodology used in catecholamine research; the cardiovascular system is the only area in which any clinical correlations are considered; the central nervous system is ignored; controversial subjects such as compartmentation or metabolic pools of norepinephrine are avoided; there is nothing about the role of nerve growth factor in the development of the sympathetic nervous system; and some important, relatively new information (for example, the release of dopamine-beta-hydroxylase from sympathetic nerves and its presence in blood) probably was still unpublished when the monograph was sent to the publisher. These omissions will not seriously hamper the reader's gaining an overview of current concepts, but the author might have included a list of other reviews and monographs which could be used to build on the foundation provided by this relatively brief introduction.

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Chemical Processes

Inorganic Reaction Mechanisms. JOHN O. EDWARDS, Ed. Interscience (Wiley), New York, 1970. x, 350 pp., illus. $15.95. Progress in Inorganic Chemistry, vol. 13.

Those who investigate mechanisms of reactions must always be aware that each specific reaction has its own characteristics; yet they hope the results on a specific system will aid in formulating a general scheme of reactivity for a class of reactions. As a field of investigation—in this case, inorganic reaction mechanisms in solution—matures, the need to keep this general view while sharpening the focus increases. It is encouraging that in the volume under consideration several contributors have attempted to meet this need.

Cattalini's discussion of substitution in square planar complexes and Chaffee and Edwards's chapter on the importance of the role played by intermediates containing both oxidant and reductant in some nonmetallic systems are examples: In Cattalini's chapter, the data for many Pt(II) complexes are compared with more limited data on Rh(I), Pd(II), and Au(III) complexes, and from these comparisons the author makes arguments about the nature of the transition states and expanded coordination number intermediates as a function of metal ion identity. The article by Kustin and Swinehart is exceptional in the incisiveness of both the questions examined and the route taken to the answers. This chapter stresses the importance of the structure and rate of solvent exchange in describing metal-ion complexation processes. The rates at which the various lanthanide ions react with ligands, and especially the sudden decrease in reactivity in the second 7 of the 14 tripositive ions, well illustrate the authors' premise. It is somewhat disappointing to me, however, that there is no extended speculation on what structural and electronic properties of aquo metal ions lead to a choice between associative and dissociative mechanisms.

The chapter on peroxide reactions stresses the Fe(III)-catalyzed decomposition of hydrogen peroxide. The authors argue that the classic, Haber-Weiss, free radical mechanism of the ferric-hexaquo-ion-catalyzed reaction is not satisfactory, and stress the role of species such as $FeOOH^{2+}$ and FeO^{3+} in this reaction. They generalize this inorganic model to the catalase- and hemin-catalyzed decompositions. This chapter provides many interesting (admittedly biased) interpretations. Other reviews include a well-referenced chapter on binuclear cobalt complexes and a discussion of non-bridging ligand effects in oxidation-reduction reactions of metal complexes.

This collection offers several high-quality reviews and enough information of general interest to chemists and biologists dealing with related problems to warrant attention. The index is well done and the errors detected by this reviewer were few. Although not a complete survey of inorganic mechanisms, the book will serve a useful purpose.

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Concepts of Force

Force in Newton's Physics. The Science of Dynamics in the Seventeenth Century. RICHARD S. WESTFALL. Macdonald, London, and Elsevier, New York, 1971. xii, 580 pp., illus. $23.95. History of Science Library.

The literature on 17th-century dynamics is varied and plentiful, yet Westfall has succeeded in filling an empty slot. His book is the first account of the whole field since Dugas's *La Mécanique au XVIIe Siècle* of 1954, and is in fact the first extensive account in English. This alone makes its publication an event of special interest to historians of science and historically minded physicists.

Westfall's principal objective is to present a critical study of the growth of Newton's concept of force, both as a conceptual tool in his dynamics and in its relations to his philosophy of nature. Since Newton's dynamics cannot be properly understood without an appreciation of the 17th-century legacy he inherited, a secondary objective is to trace the development of dynamical ideas from Galileo to Leibniz. This is a sizable program, and difficult to carry out satisfactorily. To my mind, Westfall has achieved his purpose only to a moderate degree: there is a striking imbalance in structure and content, and considerable unevenness in interpretation.

Take the structural imbalance. The main title notwithstanding, less than half the book (the final two chapters) is devoted to Newton, though admittedly this asymmetry is mitigated by the much greater amount of detail that distinguishes the chapters on Newton. Moreover, Westfall does not always show clearly how Newton's ideas relate to the very wide range of dynamical thinking that preceded him (obvious exceptions being that of Galileo, Descartes, and Huygens); a fair proportion of the pre-Newton material, though wholly welcome in itself, does not do very much to illuminate Newton's own thought.

There are some unexplained omissions. I note with pleasure the great number of thinkers Westfall discusses: Galileo, Descartes, Gassendi, Hobbes, Baliani, Mersenne, Marcus Marci, Torricelli, Huygens, Pardies, de Chales, Wren, Wallis, Hooke, Borelli, Mariotte, Roberval, and Leibniz. But with a list already as long as this, why omit discussion of Isaac Beeckman, whose dynamical ideas strongly influenced Descartes and are of greater interest than those of (say) Hobbes? Or the Cartesian Malebranche, who wrote copiously on the collision problem, yet who is mentioned only once, in a footnote? Or Honoré Fabri, who is not mentioned at all?

The interest and value of the book are increased by Westfall's decision not to confine his analyses to force as a conceptual entity, but to examine also dynamical and physical problems in which the concept figured importantly. This being so, it is disappointing to find no mention of the problem of center of percussion as treated by Descartes, Roberval, or the aforementioned Fabri. Had Westfall examined Descartes's treatment of this problem he would surely have revised his claim that "the most important step he [Descartes] took in the direction of a mathematical mechanics was his analysis of impact" (p. 89). Given that this same analysis of impact is crucial to an understanding of Descartes's and indirectly Newton's concepts of force, it is depressing to find no reference to the Scholastic notion of modal contrariety between motion and rest, without which Descartes's rules of impact are unintelligible, and no reference to the principle of least change of incompatible modes, which Descartes himself showed was an essential component in the demonstration of his rules and which is an embryonic form of the principle of least action.

On the positive side, there are interesting chapters on Galileo and Leibniz and a fine chapter on Huygens. It is particularly pleasing to have this short study on Huygens, who for some reason has never attracted the same attention as Galileo, Descartes, or Newton but whose attempt to reduce mechanics to kinematics, a feature of his thought underlined by Westfall, was an important turn in 17th-century dynamics. The many sections on the lesser-known figures mentioned above contain much material not easy to obtain elsewhere; from these very useful

surveys I might single out an analysis of Torricelli's tussle with the force of percussion.

On the critical and interpretative level, there are some comments I think ought to be made. The chapter on Descartes does not lack interest, and is often stimulating, but as a guide to the fundamental theses of Cartesian mechanics it is on the whole superficial and at times simply erroneous. It adds little to (and in places even subtracts from) the work of Koyré, Costabel, Gueroult, and others. One major error is the assertion that the Cartesian distinction between a body's "force of motion" and "the determination of its motion" corresponds to the distinction between the force of motion and the direction of motion. A careful study of the texts in which the concept of determination plays a part shows that by "determination" Descartes understood something like "the directional mode of force." This is not a quibble, for Westfall's error leads to a general misconception concerning Descartes's dynamics, typified by his mystifying remark that "a simple reflection like that of [a] ball [rebounding from a hard surface] entails no dynamic action whatever" (p. 67). This misreading not only vitiates Westfall's assessment of Descartes, it has unfortunate ramifications in the chapter on Leibniz, where he writes that Leibniz rejected the Cartesian distinction between force and determination and then goes on to give an analysis of Leibniz's use of the latter concept which indicates that it was precisely the Cartesian idea of determination that Leibniz had in mind.

Westfall also misreads Descartes's analysis of the problem of circular motion in claiming that "he employed a conceptual scheme which treated the tangential path as the resultant of a circular motion and a radial tendency away from the center" (p. 81). The converse was the case: the circular motion and the centrifugal tendency were both, in different ways, resultants of the revolving body's innate and primary endeavor to pursue uniform rectilinear motion along the tangent.

The chapters on Newton are well documented and contain shrewd insights into his dynamical thought. Nonetheless, they are not free from confusion and misinterpretation. The principal thesis that emerges from the book is that the mechanical philosophy, according to which natural phenomena were to be explained in terms of material particles in motion and interacting with each other only via discrete impulses transmitted by contact, was in the long run inimical to the development of dynamics. It was Newton who made possible the creation of a completely quantifiable dynamics by introducing the notion of continuously acting attractions and repulsions into his philosophy of nature. This is an important thesis, and certainly worth presenting and defending. I do not find Westfall's defense of it convincing, however. In his study of Newton he seems to me (i) to confuse "force" as a mechanism proposed to account for phenomena (for example, the models of impact and attraction) with "force" as a dynamical concept designed to codify the phenomena and their explanatory mechanisms in terms of mathematical laws, and (ii) to blur the distinction between the physical transition from a model of discrete impact to one of continuous attraction or repulsion and the mathematical transition from an analysis of the discrete model in terms of force quantified as Δmv to an analysis of the continuous model in terms of force quantified as Δmv in a given time, that is, effectively as *ma*.

Westfall is correct in spotlighting the fact that prior to the *Principia* Newton entertained side by side two kinds of force: that which maintained a body in "inertial" motion, and that which caused changes in its inertial motion. Yet he spoils the whole case by claiming (pp. 490–491) that with the *Principia*,

> after a fruitless flirtation with an absolutistic dynamics, in which the force of a body would express its absolute motion, he abandoned completely the conception of force as *mv*, the force of a body's motion. Phrases about bodies moving by their inherent force alone, artifacts left behind in the historical development of his dynamics, should not be allowed to mislead us on that score.

It is precisely Westfall's refusal to take these phrases in the *Principia* seriously (assuming of course that Newton meant what he wrote and wrote what he meant—a moderately reasonable assumption) that has misled him. This misunderstanding of Newton post-1687 derives ultimately from the belief—pervading the whole book, though seen at its most damaging in the chapters on Newton—that the 17th-century "principle of inertia" can be interpreted in the modern sense of a principle specifying an uncaused physical state of body, in which no force whatever is associated with the body in inertial motion. This belief is not supported by the historical facts. In particular, it is not true with respect to Newton, who held, right up to the third edition of the *Principia*, that a body is maintained in free uniform rectilinear motion by its "innate force" (the *vis insita*), measurable by the quantity of motion (mv), and also that this "inertial" motion can be changed by an "impressed force" (the *vis impressa*), measured by the *change* in quantity of motion.

Westfall's mistaken belief consequently leads him into all sorts of trouble. For example, he writes (p. 363):

> . . . two major ambiguities associated with the concept of force remained. Is force the measure of motion or the measure of change of motion? If it is the latter, is its paradigm case impact or free fall, is it measured by Δmv or by ma? These questions remained to plague the composition of the *Principia*.

Comparison of Newton's texts with Westfall's discussion of them invites the speculation that Newton was less plagued by these questions than Westfall is. The second major ambiguity becomes less problematic when it is noted that in the *Principia* Newton explicitly distinguishes between "impressed force" (quantified as above) and the "accelerative quantity of [centripetal] force," quantified as being "proportional to the velocity which it generates in a given time"—a distinction to which Westfall devotes inadequate attention.

To be paradoxical in conclusion, Westfall's study is both stimulating and confusing, both defective and valuable. Specialists will find a lot to criticize, yet I hope they will agree that it is a book that needed to be written. I certainly welcome its appearance.

There are five informative appendices on the usages of the term "force" by Galileo, Descartes, Gassendi, Huygens, and Borelli, two on Newton's usages of "impressed force" and "action," and an extensive (though not at all complete) bibliography of literature on mechanics in the 17th century. The index is well prepared.

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Reports

Multivariate Analysis of an Early Hominid Metacarpal from Swartkrans

Abstract. *Discriminant analysis permits hand bones of living primate genera to be represented as swarms of points in a multidimensional statistical framework within which intergroup relationships, and the affinities of fossil forms, can be examined. The metacarpal of* Paranthropus *from Swartkrans, South Africa, was so located with respect to groups of monkeys, apes, and modern man. The results suggest that the fossil metacarpal may be functionally similar to that of chimpanzees.*

In 1949, Broom and Robinson (*1*) announced the recovery of a complete left first metacarpal (SK 84) from the cave breccias at Swartkrans, South Africa. This bone, attributed to *Paranthropus*, has been described in detail by Napier (*2*), who sees in it a rather confusing combination of pongid and hominid features with the former predominating. Le Gros Clark (*3*) has called attention to possible conformity of the proximal articular surface of the Swartkrans specimen with the corresponding surface of the Olduvai trapezium, associated with a hand whose overall primitiveness has been emphasized (*4*).

Because of the apparent intermediacy in form of SK 84 and the importance of this bone in continuing discussions of early hominid hand function, a new multivariate statistical approach to the fossil has been undertaken. Toward this end, measurements were made on series of 44 adult male and female East African Negro metacarpals from the Galloway Collection of Makerere University, Kampala. Additional materials examined include samples of 14 *Gorilla*, 18 *Pan*, 14 *Pongo*, 5 *Hylobates*, and 10 *Papio* specimens, all fully adult and in good condition, drawn from American, British, and African collections. The 12 measurements taken with a Helios dial caliper and with a specially constructed coordinate caliper are listed in Table 1. The multivariate technique most suitable for deploying the several extant genera in meaningful fashion and thus for providing a framework within which the fossil can be located is that of discriminant analysis. Here the original measurements are used to determine orthogonal axes (discriminant functions), to a possible total of one less than the number of populations represented, upon which each individual can be plotted by means of a single discriminant score. This approach has been widely employed in studies of cranial and dental remains of modern man and has also been applied to advantage in some recent investigations of hominid postcranial fossil materials (*5*).

In the present analysis, the first three functions extracted together account for over 99 percent of all discrimination, and these three only are retained. Each may be described in turn.

Function 1, which accounts for a major portion (61.5 percent) of the total generalized variance, contrasts the modern *Homo sapiens* males and females receiving high mean scores with the orangutans, which show lower, negative, scores (see Fig. 1). Gorillas and chimpanzees are more or less intermediate on this scale. This particular sequence or distribution of centroids does not lend itself immediately to any functional interpretation in terms of overall hand posturing or manipulative ability of the thumb. There is a tendency for the hands of terrestrial genera (*Homo, Gorilla*) to be contrasted with those of the highly arboreal forms (*Hylobates, Pongo*), and *Pan* is properly intermediate, but the ground-living baboons are somewhat out of place in any locomotor spectrum of this kind. Similarly, while "truly" opposable thumbs (*Homo*) receive positive scores, and groups with far less efficiently opposable thumbs (*Pongo*) generally score negatively, any interpretation of this axis as a reflector of pollical capability must remain limited and tentative.

Further interpretation of the significance of the discriminant is best done by reference to the original measurements and the relative contributions that these make to the function. When viewed in "scaled vector" form (Table 1), this first axis is seen to be determined largely by breadth measures of the distal extremity (distal articular

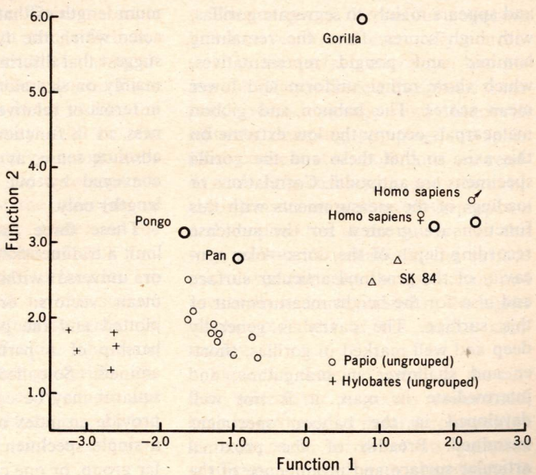

Fig. 1. Distribution of group centroids and ungrouped subjects on the first two discriminant functions (1 and 2), which together account for almost 91 percent of the total discrimination achieved. Two possible positions are indicated for the Swartkrans metacarpal (SK 84); these differ slightly depending on whether the peculiar distal "beak" on the bone is included in one of the measurements (distal articular height) used in the analysis. A third axis, perpendicular to the plane of 1 and 2, places the fossil close to *Pan* and the ungrouped specimens and far from the larger genera (*Gorilla, Homo, Pongo*).

Table 1. The first three discriminant functions in scaled vector form and correlations of the original measurements with the discriminant scores. All measurements were recorded to the nearest 0.1 mm or, where appropriate, to the closest whole degree.

Measurement	Function 1		Function 2		Function 3	
	Scaled vector	Correlations	Scaled vector	Correlations	Scaled vector	Correlations
Maximum length	−6.12	0.11	1.05	0.65	15.20	0.97
Midshaft subtense*	0.36	−0.41	−0.01	0.19	−0.45	0.39
Midshaft angle†	−1.46	−0.48	−0.34	−0.01	2.12	0.07
Proximal articular breadth	−0.16	0.53	−1.25	0.66	−2.27	0.60
Proximal articular substence (medio-lateral)	−0.81	0.14	2.36	0.47	−0.88	0.49
Proximal articular height	−1.59	0.40	0.84	0.74	−0.51	0.68
Proximal articular subtense (dorso-volar)	−1.05	−0.02	3.02	0.79	−1.33	0.32
Transverse breadth at midshaft	0.14	0.64	1.96	0.66	−2.42	0.46
Height at midshaft	1.87	0.50	0.33	0.64	−0.81	0.54
Distal articular breadth	5.76	0.86	−2.81	0.31	−0.99	0.49
Maximum head breadth	3.89	0.65	3.71	0.70	5.13	0.68
Distal articular height	−2.05	0.41	−1.76	0.50	0.20	0.68

* A measure of longitudinal curvature of the shaft. † Computed from the subtense to show curvature in degrees.

breadth and maximum head breadth) and by overall length of the bone. These same breadth dimensions, accompanied by midshaft transverse diameter and breadth of the proximal articular surface, are also highly correlated with the function, although maximum length is not. These correlations of the individual discriminant scores with each of the measurements provide the more useful interpretive index, and results suggest that transverse breadths, most likely related to robusticity of the bone, are closely associated with discrimination. The appreciable negative loadings of midshaft subtense and angle indicate that longitudinal curvature of the metacarpal shaft, or lack thereof in the case of human materials, is also being registered here.

The second discriminant accounts for some 29 percent of the total variance and appears mainly to segregate gorillas, with high scores, from the remaining hominid and pongid representatives, which show rather uniform and lower mean scores. The baboon and gibbon metacarpals occupy the low extreme on this axis, so that these and the gorilla specimens are antipodal. Correlations or loadings of the measurements with this function are greatest for the subtense recording depth of the dorso-volar concavity of the proximal articular surface and also for the height measurement of this surface. The cavity is generally deep and well marked in gorillas, shorter and shallower in orangutans, and intermediate in man; it is not well developed in the baboon specimens examined. Breadth of the proximal articular surface and prominence of the lateral convexity also receive notable loadings (the latter having a high scaled weight as well), so that the function appears primarily to reflect differences in the configuration of the saddle-shaped articulation of the metacarpal base. Various other breadths, of the head and at midshaft, are again associated with the discrimination obtained, but their contribution is not easily understood from the information at hand.

Finally, the third function, responsible for only about 8 percent of discrimination, provides some separation of the several genera along an axis perpendicular to the plane of the discriminant space in which the first two functions lie. Here *Gorilla* and *Pongo* are opposed to *Pan* (and also the gibbons and cercopithecoids) at the lower end of the scale, while *Homo* occupies an approximately central position. This patterning of the group mean scores and also the important role of maximum length as that morphological character which the function is registering suggest that discrimination is here based mainly on size alone: size measured not in terms of relative robusticity or stoutness, as in function 1, but rather in an absolute sense, as with the information conveyed by one dimension (such as length) only.

These three functions together delimit a tridimensional discriminant space or universe within which the group mean vectors, or centroids, can be plotted and the probable group membership of a particular individual examined. So-called classification chi-squares may be computed and used to provide an index of the extent to which a single specimen resembles a particular group, or one centroid resembles another (*6*). In the case of the five original hominid and pongid samples (*7*), the computed chi-squares assign 92 out of 104 specimens (88.5 percent) to the correct group; that is, the chi-square "distances" relating individuals to centroids are lower for the correct group than for any other. Eleven of the 12 "misassignments" are by sex within *Homo*, and if these errors are discounted the measure of discriminant accuracy exceeds 99 percent. Discrimination of the extant genera on the basis of 12 measurements of the metacarpal is thus quite satisfactory, and the major sources of variation between these groups seem at least partially identifiable. The statistical framework developed should provide a useful tool for assessing the affinities of the fossil bone.

In its position on the first and relatively the most important of the three discriminant axes, the fossil is allied with modern man and the gorillas; it recives a score close to the mean of the latter but falling well outside of the expected .05 probability limits of the chimpanzee and orangutan sample distributions computed for function 1 singly. Function 2, when also looked at independently, places the Swartkrans thumb in the midst of several human and pongid distributions and close to many of the baboon and gibbon specimens plotted. But here any gorilla resemblance is strongly ruled out, largely by virtue of metacarpal base characteristics which this axis seems to measure. The third discriminant has the effect of removing the fossil somewhat from the human centroids while associating it with *Pan* alone among the original groups tested.

In terms of chi-squares computed with the use of scores on all three discriminants together, and hence in total morphological pattern as assessed by the 12 measurements taken, SK 84 is excluded with 95 percent probability from membership in any group, including *Homo sapiens*. The closest approach by the fossil to a centroid in the discriminant space occurs in the case of *Pan*, the sample to which assignment is subsequently made and in fact the only group for which membership is not excluded with 99 percent probability. (Chi-squares relating the fossil to the chimpanzee centroid are 8.36 and 10.12 with three degrees of freedom, for distal height measurements including and omitting the beak, respectively.)

This does not, of course, prove that *Paranthropus* at Swartkrans possessed a thumb (or hand) precisely like that of a modern chimpanzee. But a degree of similarity is certainly implied, with respect to measurable morphological structure and presumably in matters of function as well. The chimpanzee metacarpal and thumb are short relative to the other digits, and there is some limitation on movement at the carpometacarpal joint imposed by the surrounding "cuff" of thenar musculature (*8*). Thus, despite the potential for mobility at the well-developed saddle joint, the animal is seldom, if ever, observed to oppose the pulp of the thumb to the pulp surface of one or all of the remaining fingers. A true "precision grip" is not performed, although various imperfect approaches to this grip are possible (*8, 9*). The degree of thenar muscle development, the morphology of the articular capsule itself (whether loose or closely constructed), and the relative lengths of the pollex and other digits are unknown for *Paranthropus*, but in overall length and articular surface configuration, and in other characteristics emphasized in the discriminant analysis, the fossil metacarpal approximates the chimpanzee condition and may thus have fitted a hand with similar functional limitations.

In any case, despite its robust nature and tentative association with specimens of *Homo* on functions 1 and 2, the Swartkrans bone is far from fully modern in its morphology. Further study of such materials, including the judicious application of multivariate statistics, is necessary in order to detail the locomotor and manipulative capabilities of *Paranthropus* and early *Homo*.

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Enrichment of Heavy Metals and Organic Compounds in the Surface Microlayer of Narragansett Bay, Rhode Island

Abstract. *Concentrations of lead, iron, nickel, copper, fatty acids, hydrocarbons, and chlorinated hydrocarbons are enriched from 1.5 to 50 times in the top 100 to 150 micrometers of Narragansett Bay water relative to the bulk water 20 centimeters below the surface. Trace metal enrichment was observed in the particulate and organic fractions but not in the inorganic fraction. If these substances are concentrated in films only a few molecular layers thick on the water surface, the actual enrichment factor in the films may be well over 10⁴, resulting in extremely high localized pollutant concentrations in the surface microlayer.*

From a pollution standpoint, the air-sea interface is perhaps one of the most important but most poorly characterized regions of the marine environment. The surface microlayer of the ocean has many unique chemical and physical properties, most of which are little understood. The organic and trace metal chemistry of this microlayer has received scant attention. The few studies of this region (*1*) indicate the presence of a variety of surface-active substances (for example, fatty acids and fatty alcohols) at the interface. These materials often form a coherent film which becomes evident as a result of the localized damping of capillary waves. Even when this film or slick is not visible, the surface microlayer may still be enriched with surface-active compounds. The major source of these compounds in the open ocean is the reservoir of natural marine organic matter in the mixed layer. The process of slick formation is complex, but surfactants are probably concentrated in the surface microlayer by convection currents, rising bubbles, and diffusion. The most surface-active of these materials displace the less active compounds, and eventually the microlayer is enriched with lipoid material and a coherent slick is formed.

Many pollutants may be concentrated and stabilized in this layer after its formation or may in fact be incorporated into it directly. This is especially true for lipophilic pollutants such as chlorinated hydrocarbons (*2*) and petroleum hydrocarbons. Trace metals may also be concentrated in the microlayer. Organic acids, proteinaceous material, and other surface-active organic substances may provide complexing sites for many heavy metals and thus be responsible for the transportation and concentration of these metals at the water surface.

The sources of the various pollutants that can reach and eventually concentrate in the surface microlayer are numerous. They include atmospheric transport, rivers, sewage and industrial effluents, dumping, pumping, and spills. Once concentrated, pollutants are readily accessible to bacteria and other microorganisms as well as phytoplankton and zooplankton at the surface. In this way, pollutants initially in the surface microlayer can enter the food chain and eventually be concentrated in the higher trophic members of the marine community.

Since the chemical nature of the surface microlayer is poorly understood, both in terms of its natural composition as well as in terms of its pollution gradients, it would seem appropriate to characterize more fully this region of the marine environment. This report de-

Table 1. Concentrations and enrichment factors of organic compounds and metals in surface microlayer samples from Narragansett Bay, Rhode Island.

Substance	Sample 1			Sample 2		
	Concentration (μg/liter)		Enrichment* factor	Concentration (μg/liter)		Enrichment* factor
	Surface	Subsurface		Surface	Subsurface	
Fatty acids	128 ± 26	36 ± 7	3.6 ± 1.0	94 ± 19	62 ± 12	1.5 ± 0.4
Hydrocarbons	NA†	NA†	NA†	8.5 ± 1.7	5.9 ± 1.2	1.4 ± 0.4
PCB's‡	4.2 ± 1.0	0.15 ± 0.04	28 ± 10	0.45 ± 0.11	≦ 0.05	≧ 9
Lead						
Particulate	1.4 ± 1.1	0.24 ± 0.17	5.8 ± 6.1	1.5 ± 0.2	0.28 ± 0.10	5.4 ± 2.0
Organic	1.0 ± 0.8	0.36 ± 0.06	2.7 ± 2.2	1.4 ± 0.6	0.27 ± 0.12	5.2 ± 3.1
Inorganic	1.7 ± 0.3	2.7 ± 0.5	0.6 ± 0.2	6.1 ± 1.4	3.7 ± 1.0	1.6 ± 0.6
Iron						
Particulate	820 ± 47	28 ± 4	29 ± 5	35 ± 7	8.2 ± 1.2	4.3 ± 1.1
Organic	3.7 ± 1.5	0.60 ± 0.33	6.2 ± 4.3	5.1 ± 2.3	3.8 ± 0.8	1.3 ± 0.6
Inorganic	2.8 ± 0.4	1.4 ± 0.2	2.0 ± 0.3	17 ± 8	12 ± 1	1.4 ± 0.7
Copper						
Particulate	7.2 ± 2.3	0.20 ± 0.09	36 ± 18	1.3 ± 0.4	0.26 ± 0.11	5.0 ± 2.7
Organic	5.6 ± 0.5	0.19 ± 0.11	29 ± 17	1.6 ± 1.0	0.11 ± 0.04	15 ± 11
Inorganic	3.4 ± 0.4	3.3 ± 0.3	1.0 ± 0.2	1.5 ± 0.6	1.3 ± 0.4	1.2 ± 0.6
Nickel						
Particulate	11 ± 3.0	0.2 ± 0.1	50 ± 30	13 ± 5	2.1 ± 0.3	6.2 ± 2.5
Organic	4.9 ± 2.6	0.48 ± 0.33	10 ± 8.7	5.0 ± 0.6	1.8 ± 0.7	2.8 ± 1.1
Inorganic	11 ± 4.0	14 ± 1.0	0.8 ± 0.3	21 ± 5	16 ± 2	1.3 ± 0.3

* The enrichment factor is equal to the surface concentration divided by the subsurface concentration. † NA, hydrocarbons not detected because of limited sample. ‡ PCB's expressed as Aroclor 1254.

scribes our efforts to determine the distribution of fatty acids, hydrocarbons, chlorinated hydrocarbons, and trace metals in samples from Narragansett Bay, Rhode Island.

Several surface microlayer samples were collected near the mouth of the west passage of Narragansett Bay (41°30′20″N, 71°23′30″W; 41°34′30″N, 71°23′W). The area is designated class SA (Rhode Island Department of Health) and is free of industrial and municipal effluents and major ship traffic. Samples for trace metal analysis were collected on a polyethylene screen (75 by 75 cm, 20 mesh) mounted on a Plexiglas frame. After the screen had been rinsed in seawater several times, it was submerged in the water and then passed back up through the water surface with the screen approximately parallel to the water surface. The frame was allowed to drain for 10 seconds, and then the screen was drained for 60 seconds into a polyethylene container through a polyethylene funnel. This collector samples the top 100 to 150 μm of the water surface (*3*). Polyethylene gloves were worn throughout the collection, and great care was taken to ensure that the sample was not contaminated by the collection boat (an aluminum rowboat) or the individuals doing the collecting.

Samples for organic analysis were collected on a 16-mesh circular stainless steel screen, 30 cm in diameter, in a manner similar to that used for trace metal sampling. The screen was drained into a Teflon bottle through a glass funnel. Subsurface samples were collected by submerging a Teflon bottle approximately 20 cm below the water surface and then removing the cap (polyethylene gloves were worn during this collection). Sample collection was limited to periods when wind conditions were less than 12 to 15 knots (22 to 28 km/hour) and wave heights were less than 3 feet (91 cm). The collection time was approximately 1½ to 2 hours per station.

Surface microlayer samples for organic analysis were acidified and extracted with chloroform after the addition of fatty acid and hydrocarbon internal standards (*4*). The chloroform extract was evaporated under reduced pressure, dissolved in a mixture of benzene and methanol (1 : 1), and divided into two equal portions for lipid and chlorinated hydrocarbon analysis.

The sample for lipid analysis was saponified and then methylated to convert total fatty acids (free and esterified) into methyl esters (*5*). The methyl esters and hydrocarbons were isolated and purified by preparative thin-layer chromatography. Qualitative and quantitative analyses were carried out with a gas chromatograph (Hewlett-Packard model 700) equipped with a flame ionization detector. The samples were analyzed on polar (diethylene glycol succinate or free fatty acid phase) and nonpolar (Apiezon L) columns, and relative retention times were compared to those of authentic fatty acid and *n*-alkane hydrocarbon standards. In addition, the fatty acids were analyzed on these columns after hydrogenation. Quantitative results were obtained by comparing the areas of naturally occurring component peaks to the area of the internal standards. The results obtained on standard mixtures of fatty acids and *n*-alkanes were in agreement with the stated composition data with a relative error of less than 5 and 8 percent, respectively, for major components (> 10 percent of the total mixture).

The sample used for chlorinated hydrocarbon analysis was separated into a polychlorinated biphenyl (PCB) and a pesticide fraction on a silicic acid column. The fractions were analyzed on a gas chromatograph (Tracor model 220) equipped with two ^{63}Ni electron-capture detectors and two electrometers. The samples were analyzed on two different nonpolar columns (OV-17/QF-1 and SE-30/QG-1), and the relative retention times were compared to those in authentic Aroclor and pesticide standards.

Surface microlayer samples for trace metal analysis were filtered through Millipore HA filters (47 mm, 0.45 μm) in an in-line closed filtering system constructed entirely of polyethylene and polypropylene. The collected particulate material appeared to be largely biogenic. The "particulate" sample and filter were dissolved in a mixture of perchloric and nitric acid for subsequent atomic absorption (AA) analysis. The filtrate from the particulate sample was extracted with chloroform. The chloroform, along with any interfacial material, was filtered through a Millipore HA filter (24 mm, 0.45 μm) to remove the interfacial material. The chloroform extract was concentrated in a rotary evaporator, and the final few milliliters were transferred to the 24-mm filter and evaporated. The "organic" phase on the filter was then processed in the same manner as the "particulate" sample for AA analysis. After filtration and chloroform extraction, the remaining aqueous portion of the sample was acidified and buffered to a *p*H of 3.0. The solution was then extracted with a 5 percent (by weight) solution of diethyldithiocarbamic acid into methyl isobutyl ketone. This "inorganic" phase was analyzed directly by AA. All AA analyses were performed with an atomic absorption spectrophotometer (Perkin-Elmer model 303) with standards prepared in a seawater matrix.

We have collected several surface microlayer samples in Narragansett Bay and analyzed them for trace metals, lipids, and chlorinated hydrocarbons. The results of the analysis of two of these surface slicks and subsurface waters are presented in Table 1. Sample 1 was collected in a heavy frothy surface slick and showed enrichment factors in the surface microlayer relative to those in the subsurface water ranging from 3 to 50 for fatty acids, PCB's, and "particulate" and "organic" trace metals. Sample 2, from a less pronounced slick, had lower enrichment factors varying from slightly over 1 to 15. With the exception of iron in sample 1, no enrichment was found for trace metals in the "inorganic" phase for these or other surface microlayer samples collected in Narragansett Bay. In general, the fatty acids were normal saturated and monounsaturated acids and ranged from 12 to 20 carbons in chain length. Only three hydrocarbons were detected in these samples, and they were tentatively identified as having carbon numbers of $C_{21.0}$, $C_{22.5}$, and $C_{24.0}$ relative to *n*-alkanes on an Apiezon L column. The only chlorinated hydrocarbons found were PCB's which were measured as Aroclor 1254.

An enrichment factor given in Table 1 for any of these substances in the top 100 to 150 μm of the water surface suggests a much greater enrichment in the film material itself. If the film layer is monomolecular, as has been suggested (*1*), it should have a thickness of about 2×10^{-3} μm. If the film thickness is estimated conservatively as five molecular layers (10^{-2} μm) and all the chemical enrichment is in this layer, the actual concentration in the film would be 1.5×10^4 times the concentration in the top 150 μm. In sample 1, where the enrichment of PCB's in the top 100 to 150 μm is 28, the PCB concentration would be ~ 60 parts per million, which would represent an enrichment of 4×10^4 in the film layer itself. The effects of the high concentrations of chlorinated hydrocarbons, lipids, and heavy metals on the diversity and species composition of the bacteria, phytoplankton, and zooplankton living in the surface microlayer are unknown.

Pollutants present in the surface microlayer of the coastal zone may easily be introduced into the atmosphere for subsequent transport to open ocean waters. The surface of the ocean is a major source of atmospheric particulate matter. The primary production mechanism for these particles is the breaking of bubbles, which ejects particles both from a central jet and from the ruptured bubble film cap (*6*). There is evidence that these particles are chemically more representative of the surface microlayer than the bulk water underneath (*7*), and thus this study suggests that the particles may be considerably enriched in pollutants if they are generated in highly polluted nearshore areas.

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Cloud Seeding Experiments: Lack of Bias in Florida Series

Abstract. *There has been concern about the possibility of selection bias in cloud seeding experiments. Covariates and experimental design have been used to obtain an estimate of this bias. The results indicate that there was no selection bias in the Caribbean and Florida series of cloud seeding experiments.*

Stigler (*1*) has made the general point that selection bias may be introduced when suitable experimental subjects arrive sequentially; he referred in particular to the cloud seeding experiments in Florida. We present evidence here that such a bias is not detectable in the experiments over the Caribbean Sea (*2*) in 1965 and over Florida (*3*) in 1968 and 1970. These references should be consulted for a description of the experimental details. In addition, we wish to make a suggestion about what to do in some experimental situations where selection bias has not been (or cannot be) eliminated by some appropriate design.

In planning the Caribbean cumulus experiments, careful attention was given to the design. This included consultations with experts in experimental design, one of whom, W. J. Youden (now deceased), prepared the randomization scheme. These experiments represent the first time that a numerical model of cumulus dynamics was used to make predictions of cloud growth and to provide a measure of "seedability" of selected clouds. The power of the experiments was greatly increased by in-

corporating the model prediction into their design as a covariate, since the covariate accounted for more than 90 percent of the variance. Because the covariate made use of information available up to the time of cloud selection, it could be examined for evidence of bias in selecting the clouds for seeding or for evidence that randomization failed to balance out uncontrolled variation and to provide equivalent clouds for the two test groups (seeded and unseeded clouds). No significant difference in seedability was found, that is, the samples of seeded and unseeded clouds apparently came from the same population.

In 1968 and 1970 the site of the dynamic seeding experiments was transferred to southern Florida, where it was possible to evaluate amounts of precipitation as well as the other cloud parameters. For the statistical analysis of precipitation the important covariate was the amount of rainfall in the 10-minute period before "seeding." As before, no significant difference was found between the two groups, although the seeded clouds were very slightly wetter in this 10-minute period than the unseeded clouds. However, this slight difference (whatever its source might be) is automatically allowed for in the classical covariance analysis procedure, which makes the test on the adjusted means. Again, this illustrates the importance of making use of a significant covariate if one is available, not only to increase the sensitivity of the experiment but to indicate in the treatment groups evidence of selection bias or failure of the randomization scheme to give "equal" groups. Braham *et al.* (*4*) suggest that some of the ambiguity in the results of the Whitetop experiment (*5*) may be due to an uncontrolled background effect that was present and not balanced out by the rigorous randomization scheme.

In 1968 the randomization series was generated so that the ratio of seeded to unseeded clouds would be approximately 2/1 (it turned out to be 14/5). This was to allow for more seeded clouds so that further study could be made of the physical model. Operationally, up to five experimentally acceptable clouds were "seeded" each day. The decisions on each day were known after the aircraft landed, not after each cloud. Furthermore, in all of the experiments carried out in Florida, the selection of the clouds was often turned over to the pilots or other members of the flight crew since they had neither a vested interest in the outcome of the experiment nor a theoretical knowledge of cloud behavior.

In 1970 the original design for the single-cloud experiment involved randomizing in pairs. The first cloud of the experiment was to be selected and treated according to the randomized instruction. The second cloud was then to be given the opposite treatment. For cases in which the second cloud was chosen after experimentation with the first cloud, there might have been a strong possibility of selection bias if the experimenters were able to guess the correct instruction for the first cloud from visual observation of the resulting behavior of that cloud. We had planned to test for this bias by comparing the seeding effect of the first clouds of the randomization pairs with that of second clouds. (The seeding effect is the mean amount of precipitation from seeded clouds less the mean amount from unseeded clouds.) However, randomization by pairs did not work out because the decision for seeding or not seeding in the single-cloud experiment most often had to be contingent on the decision in the area experiment. That is, the area decision governed that for single clouds on that day. Those within the area were given the treatment required by the randomized decision for the area, while those outside the area were given the opposite treatment, so that area instructions and single-cloud instructions were intermixed in a manner complicating any rational guessing strategy of the experimenters.

It can be seen from the design and problems of execution of the 1968 and 1970 single-cloud experiments that the optimum strategy for guessing the seeding instruction before choosing the experimental cloud would be difficult to devise. However, it might be suggested that it would be easiest to make this guess for the first cloud on each day of the experiment and more difficult for subsequent clouds as the number of these increases. A comparison of the seeding effect for first clouds with the seeding effect for second clouds, third clouds, and so on does not support this contention. In fact, the seeding effect computed for first clouds was actually slightly less than that for the remaining clouds.

To demonstrate the limitations of an experimenter's ability to bias the experiment in favor of seeded clouds, the two principal experimenters guessed what the seeding instruction was after visually observing the outcome on each day of the 1971 experiment (similar guesses were made in the 1970 experiment but these were not routinely recorded). Only 3 out of 11 guesses were correct, which shows how difficult it is to draw inferences from visual observations of cloud behavior, a fact recognized by those familiar with the large variability of cumlus clouds.

In the area experiment one might suspect a possibility for bias in that it is randomized by days and the scientists learn the decision at the end of each day. However, since all the eligible clouds in the area are "seeded" on each experimentally acceptable day, there is no choice and hence no possibility for selection bias. Since the termination of the experimental periods is forced by the end of the aircraft assignment and never chosen by the scientists, it might be possible in future years not to reveal the decisions until the end of the whole period. In the past this has been unavoidable because of public concern about drought and other potential environmental disturbances in the seeding area. There have been only 12 acceptable days in the area experiment to date, and, although the results are encouraging, these are too few cases for definite conclusions.

We have been very much concerned with the possibilities of selection bias in cloud seeding experiments. We agree with Stigler (*1*) in his concern "to alert future experimenters to the dangers of bias associated with this type of experiment." However, we do not believe that selection bias was present in the Florida series of cloud seeding experiments.

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Charge Distribution in the Light-Atom Mineral Kernite

Abstract. *A charge density analysis of accurate x-ray data for the mineral kernite $Na_2B_4O_6(OH)_2 \cdot 3H_2O$ indicates that the sodium and boron atoms have partial positive charges of 0.4 to 0.5 unit and 0.4 to 0.7 unit, respectively, whereas the oxygen atoms have negative charges of about 0.4 to 0.5 unit. The best agreement with the intensities and with the experimental scale factor is obtained with contracted molecule–optimized atomic orbitals. Difference density maps based on high-order parameters show more density in B–O than in Na–O bonds, thus supporting the covalent nature of the bonds between boron and oxygen atoms.*

Information on the electronic charge distribution is of considerable importance for an understanding of the stability and atomic arrangement of a great variety of mineral structures. Some discussions on the structure of minerals have been based on completely ionic models, in which, for example, an oxygen atom would bear a negative charge of two electrons (*1*). Investigators have made calculations on the orientation of hydroxyl groups or water molecules, using full (*2*) or partial (*3*) ionic charges. But, in the frameworks which exist in many silicates and borates, interatomic distances are short and typical for bonds between covalently bonded atoms. Accepted chemical concepts would exclude large ionic charges for the atoms in such a framework. To provide further information we decided to study a number of minerals, using recently developed techniques for charge refinement of accurate x-ray diffraction data (*4*).

Because of the absence of heavy atoms (in which the many core electrons are unaffected by bonding), the absence of crystallographic disorder (*5–7*), and because thermal motion is usually small in minerals, kernite [$Na_2B_4O_6(OH)_2 \cdot 3H_2O$] is suitable for a charge density analysis. Its structure is of especial interest, since, as shown by Giese (*5*) and by Cialdi *et al.* (*6*), it contains boron atoms in both tetrahedral and trigonal positions, and bridging as well as hydroxylic oxygen atoms (Fig. 1).

Two symmetry-related sets of three-dimensional diffraction data were collected on an automated Picker diffractometer. Symmetry-equivalent reflections were averaged to a unique set of 3604 reflections [$(\sin \theta/\lambda)_{max} = 0.72$ Å^{-1}, where θ is the Bragg angle and λ is the wavelength], of which 2499 were larger than three times the standard deviation. The parameters determined by Giese (*5*) were used as input in the conventional least-squares refinement, which led to a final agreement factor $R(F)$ of 3.4 and a weighted agreement factor $R_w(F)$ of 3.6 percent, where F is the x-ray structure factor and $R(F)$ and $R_w(F)$ are specified in Table 1. Giese's positional parameters were reconfirmed, although the results presented here are somewhat more accurate than those obtained previously.

The extended L-shell method was used, in which the occupancies of spherical valence shells are varied together with the positional, thermal, and extinction parameters (*4*). The more sophisticated aspherical treatments generally require complementary information from neutron diffraction (*8*), which could only have been obtained if synthetic, ^{11}B-enriched crystals of kernite had been available. The net atomic charges are constrained so that the crystal remains neutral during the refinement.

The results of the charge refinement depend, to a certain extent, on the nature of the atomic orbitals used for a description of the valence electrons (*4*). In previous work isolated atom self-consistent field Hartree-Fock orbitals (HF) as well as molecule-optimized standard Slater orbitals (*9*) have been used in a description of the valence electrons, whereas the cores of the atoms in the first row of the periodic table were assumed to be unperturbed by bonding. In the present study an additional refinement with a molecule-optimized core (*10*) for the sodium atom was included. Resulting agreement factors, net atomic charges, and scale factors relating observed and experimental structure factors are given in Table 1. The agreement between observation and calculation, as expressed in the agreement factors, is somewhat better for the Slater type orbital (STO) valence and sodium core set (Table 1, column 4) than for the other sets of results. However, it is gratifying that

Table 1. Experimental atomic charges; HF, Hartree-Fock orbitals; STO, Slater type orbital. Parenthetical values in columns 2, 3, and 4 are standard deviations.

Atom	HF core, HF valence	HF core, STO valence	HF core (B, O), STO core (Na), STO valence
Na(1)	+ 0.43(16)	+ 0.41(4)	+ 0.57(4)
Na(2)	+ .54(18)	+ .29(5)	+ .45(5)
O(1)	− .40(3)	− .33(3)	− .51(3)
O(2)	− .37(3)	− .29(3)	− .45(2)
O(3)	− .34(3)	− .29(3)	− .43(2)
O(4)	− .41(3)	− .34(2)	− .52(2)
O(5)	− .34(3)	− .35(3)	− .46(2)
O(6)	− .42(4)	− .32(4)	− .47(3)
O(7)	− .34(4)	− .20(4)	− .39(4)
O(8)	− .39(5)	− .28(5)	− .43(4)
O(9)	− .37(3)	− .33(3)	− .48(3)
O(10)	− .33(6)	− .02(6)	− .30(6)
O(11)	− .45(5)	− .32(4)	− .48(4)
B (1)	+ .28(6)	+ .40(4)	+ .50(4)
B (2)	+ .13(6)	+ .41(4)	+ .44(4)
B (3)	+ .22(5)	+ .54(4)	+ .55(4)
B (4)	+ .32(6)	+ .56(4)	+ .64(4)
H (1)	+ .32(6)	+ .22(5)	+ .35(4)
H (2)	+ .30(5)	+ .28(5)	+ .41(4)
H (3)	+ .40(5)	+ .02(6)	+ .23(6)
H (4)	+ .28(6)	− .03(6)	+ .13(5)
H (5)	+ .24(5)	+ .09(6)	+ .23(6)
H (6)	+ .27(6)	+ .01(6)	+ .16(5)
H (7)	+ .22(7)	− .14(8)	+ .08(8)
H (8)	+ .30(6)	+ .02(7)	+ .17(6)
	Scale factor k		
	1.32(2)	1.27_5(2)	1.24(2)
	$R(F)$*		
	0.031	0.032	0.030
	$R_w(F)$†		
	0.031	0.032	0.029

* $R(F) = \frac{\Sigma||F_{obs}| - k|F_{calc}||}{\Sigma F_{obs}}$ † $R_w(F) = \left[\frac{\Sigma w(F_{obs} - k|F_{calc}|)^2}{\Sigma w F_{obs}^2}\right]^{1/2}$

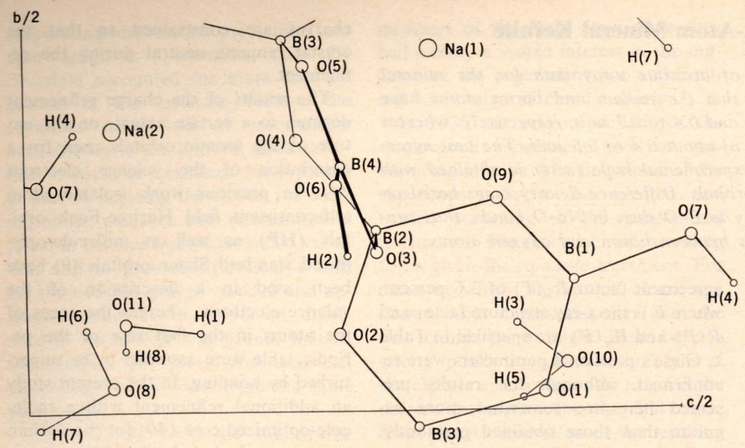

Fig. 1. Projection of the structure on the *bc* plane.

the general features are common to all three sets of results. Thus, the sodium atoms bear partial positive charges of 0.4 to 0.5 unit, whereas the boron and hydrogen atoms are positively charged and the oxygen atoms are everywhere negatively charged. This charge distribution is in agreement with the relative electronegativities of these atoms, but the charges are always several times smaller than those corresponding to a completely ionic model. Thus, the new experimental results strongly support Slater's conclusion, arrived at from a consideration of interatomic distances, that "atoms tend to be much more neutral in a crystal than a straight ionic interpretation would indicate" (*11*).

A choice from among the three sets of results is necessary for a more detailed discussion of the results. As noted earlier (*12*), the choice of atomic orbitals leads to differing values of the scale factor k, defined by

$$F_{obs} = kF_{calc}$$

the STO scale factors being considerably smaller than the scale factors obtained in the isolated atom Hartree-Fock treatment. The same effect is found in the present study (Table 1).

Thin, but extended sheets of kernite can be easily obtained because of the excellent cleavage of the crystals. By employing such a sheet larger than the x-ray beam (such that all the intensity in the beam is subject to diffraction) and measuring the direct and the reflected beams for a series of reflections, we have succeeded in obtaining an experimental value for k in our original data set. The experimental value of 1.23 ± 0.015 indicates *that the molecule-optimized Slater type orbitals of Hehre* et al. (*9*) *give a better description of the valence electron distribution in the crystal than the HF results obtained on isolated atoms.* This experimental value does not, within the experimental errors, distinguish clearly between the models represented by the last two columns of Table 1, although the k value obtained with the model of column 4 is in better agreement with that of the experiment than the other k values. Because this model also gives the lowest x-ray agreement factors, it will be used in the following discussion.

The most significant conclusion to be drawn from a detailed analysis of the net charges is the lack of distinction according to chemical environment. Thus, the charges on the sodium atoms are equal to within the experimental errors, even though the coordination is somewhat different, with Na(1) and Na(2) showing six- and fivefold coordination, respectively. Similarly, no difference is found between the bridging oxygen atoms O(1), O(2), O(3), O(4), O(5), and O(9); the hydroxylic oxygen atoms O(6) and O(7); and the water oxygen atoms O(8), O(10), and O(11). The averages over the charges in these three groups are -0.47_5, -0.43, and -0.40 positive units, respectively, with a fairly large range of values in each group. In earlier stages of the refinement it appeared that the tetrahedrally coordinated baron atoms B(2) and B(3) were less positively charged than the trigonally coordinated B(1) and B(4) atoms, but the final results show no clear differentiation. According to a valence bond diagram, a tetrahedrally coordinated boron atom bears a formal negative charge of one electron, but it appears that there is no relation between this idealized situation and the actual charge distribution.

Further information on the charge distribution is provided by difference density maps. Since the least-squares, curve-fitting procedure tends to produce difference maps in which bonding effects have been compensated for by adjustment of parameters, we have performed a second least-squares refinement, using only high-order data with $(\sin \theta/\lambda)_{min} > 0.6$ Å^{-1}. The resulting parameters are less affected by bonding, and they were used in the calculation of a number of maps showing the observed minus the calculated spherical atom density. In these maps (not shown here because of space limitations), density is observed between the boron and oxygen atoms, which further supports the covalent nature of these bonds. Corresponding maps through planes containing the sodium atoms show little density between the sodium and oxygen atoms, indicating that the bonds between these atoms are more ionic.

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Spacecraft Propulsion: New Methods

Abstract. *Cosmic plasmas contain energy which may be tapped and used for spacecraft propulsion. The energy needed for launching a spacecraft could be supplied to it from the ground through a plasma channel in the atmosphere.*

In a fascinating article entitled "The Relevance of Space," Arthur Kantrowitz (*1*) pointed out that the cost of the kinetic energy needed to put a 3000-kg spacecraft into orbit is less than $150 under the condition that the energy can be bought at the price a consumer of electricity on the ground is paying. This means that one of the reasons why space activity is so expensive is the extremely inefficient way energy is used for spacecraft propulsion. This is partially a result of the low exhaust velocity of the rocket gases, which implies that the total starting weight of the spacecraft must be two or three orders of magnitude larger than the payload.

An ingenious way of reducing the ejected mass is used in the electric propulsion devices developed by Ernst Stuhlinger (*2*) and others. By ejection of a plasma one can easily reach exhaust velocities of several tens of kilometers per second. The result is that the ejected mass may be of the same order of magnitude as the payload and the efficiency very high. The present limitation of this spacecraft propulsion device is that it draws its energy from solar panels, which, for mechanical reasons, cannot be made to deliver more than about 10 kw each. A nuclear reactor in the spacecraft may give much higher power, but it is a complicated and unpleasant device.

I shall discuss here some possible ways of furnishing a spacecraft with power to be used in a plasma propulsion motor.

Sailing in the solar wind. Because of its magnetization B, the solar wind, which moves radially outward from the sun with a velocity v, possesses an electric field E (seen from a fixed coordinate system):

$$\mathbf{E} = \frac{1}{c}\mathbf{v} \times \mathbf{B}$$

where c is the speed of light. With the normal values $B = 5 \times 10^{-5}$ gauss and $v = 4 \times 10^7$ cm/sec, we find (if v is perpendicular to B)

$$E = 2 \text{ volt/km}$$

a value which may increase by one order of magnitude (for example, in connection with solar flares). It may also be smaller for some periods. If a conducting cable with the length of, say, 500 km is placed in the direction of E, we could tap a voltage of 1000 volts under the condition that the transfer resistance between the ends of the conductor and the solar wind can be made small. If the cable consists of a number of wires of a superconducting material embedded in a thermal insulator, those wires that are not exposed to solar radiation may cool down by radiation so much that they become superconducting. A current of, say, 1000 amperes through the cable would give a power of 1 Mw. The project requires that three crucial problems be solved:

1) That a cable be manufactured with the required properties. In order to compete with other energy sources the power per mass must be at least of the order of 0.1 kw/kg (*2*), which means that the cable must not weigh more than 20 kg/km (*3*).

2) That the cable be deployed in space so that it becomes superconducting.

3) That electric contact be established between the solar wind and electrodes at both ends of the cable.

It seems reasonable that problems 1 and 2 can be solved. Concerning problem 3, a space-charge limited current is too small to be useful. However, if the electrodes are surrounded by a plasma, an arc discharge (or a corona discharge) may be produced. The plasma could be emitted from a gun near the electrode, or we may use the plasma which must be ejected in any case for the propulsion of the spacecraft.

It is not very obvious whether the electric contact with the solar wind will be a technically difficult problem or not. We know that the magnetosphere taps about 10^{12} watts from the solar wind (*4*). This is about two orders of magnitude greater than the solar wind kinetic energy passing a surface of the earth's cross section. (Hence, the electromagnetic tapping achieved by the magnetic field of the earth is much more efficient than a "mechanical" sail the size of the earth would be.) If in this project a power of 1 Mw is extracted, the result would just copy what nature does on a scale 10^6 times larger.

Whenever the electric vector in the solar wind changes, the "sails" must be trimmed for the new wind situation.

In principle, the extraction of energy from the solar wind may give a spacecraft a velocity of the same order of magnitude as the solar wind. This would reduce travel times in space by two orders of magnitude.

Energy transfer à la Zeus. When Apollo 12 was launched, there were low clouds but no thunderstorm. When the spacecraft had disappeared in the clouds, lightning was observed in the region of sky where the spacecraft had last been seen. This effect was interpreted as due to the exhaust gases which facilitated a discharge of electrostatic charges in the clouds down to the ground. One cannot avoid thinking that it would be preferable to transfer power up to the spacecraft in this way.

In order to put a 3000-kg spacecraft into orbit, an energy of 10^{11} joules is needed. If an acceleration of $8g$ is allowed, an average power of 1 Gw is required during 100 seconds. We can easily tap a power of this order from an electric power network, but the difficulty is to transfer it to the spacecraft.

In a thunderbolt, a number of precursory discharges produce a conducting channel between a charged cloud at, say, a height of 5 km and the ground. When this has been achieved, the main discharge takes place. Often a series of discharges follows, showing that, once the channel is ionized, it has a considerable lifetime (up to 1 second). In a typical lightning we have a dissipation of 0.5×10^9 joules (*5*), an energy comparable to what the acceleration itself requires in a fraction of a second.

If a spacecraft at launch is accelerated by two plasma guns at a large distance from each other, and electric arcs are produced between each of the plasma guns and the corresponding electrodes on the ground, it is possible that these arcs can be maintained during the launch through the atmosphere. The ground electrodes must have a voltage of several million volts, and the currents should perhaps be pulsed. If the arcs burn in the hot exhaust gases from the rocket, the power necessary to sustain them will be reduced, especially if the exhaust gases are seeded with easily ionized substances. The values given above for the power needed to make the paths of a lightning conducting seem not to exclude the possibility that an efficient energy transfer can be accomplished in this way.

If alternating current is used, it is

possible that only one transfer channel is needed. A thundercloud can store 10 to 50 coulombs. If the spacecraft is furnished with a number of sharp points, it could distribute electric charge through corona discharges to a vast region around it where charge can be stored. Also a transfer of wave energy along the conducting channel should be considered. The spacecraft must be accelerated up to a height of several hundred kilometers. When it has reached the ionosphere, the transfer problem takes on another aspect. The anisotropy of electric conduction in the earth's magnetic field could be used for energy transfer along the magnetic field lines. It is possible that the spacecraft trajectory should be made parallel to the magnetic field lines. The total power to be transmitted at the launch is comparable to the power of a very large magnetic storm. Our knowledge of the storm processes in the auroral zone will be valuable.

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Intestinal Calcium Transport: The Role of Sodium

Abstract. *The role of sodium in intestinal calcium transport was investigated in everted rat intestine. Ethacrynic acid, but not ouabain, inhibited calcium transport. However, ouabain did inhibit net water transport and, therefore, sodium transport, establishing the dissociation of the two transport processes. In addition to a magnesium-dependent adenosine triphosphatase (activated by sodium and potassium), a phosphatase dependent on sodium and calcium was localized to the lateral and basal membrane fractions of the mucosal cell. Activity of the latter phosphatase, similar to calcium transport in intact tissue, was inhibited by ethacrynic acid and not by ouabain. Sodium, therefore, may participate in the calcium transport process by activating an enzyme complex, dependent on adenosine triphosphate, that mediates calcium transport.*

Although there is controversy about the mechanism of intestinal transport of calcium, the transport process is an energy-dependent, saturable process that moves calcium against concentration and electropotential gradients (*1*). Whereas the movement of calcium across the brush border of the intestinal epithelial cell does not require sodium, the expulsion of calcium from the cell at the basal and lateral membranes is presumably dependent on sodium (*2*, *3*). The nature of this dependency on sodium is not established. This relation between calcium and sodium in the intestinal cell is reminiscent of that in the renal tubule, where inhibition of proximal tubular reabsorption of sodium by saline infusion and volume expansion or by furosamide and ethacrynic acid is also associated with inhibition of calcium reabsorption (*4*). The similarities between renal and intestinal transport mechanisms (*5*) suggest that intestinal calcium transport might also be influenced by inhibitors of renal sodium transport.

Since ethacrynic acid and ouabain have been used to delineate two mechanisms of sodium extrusion from renal tubular cells, that is, sodium exchange and net sodium transport (*6*), these inhibitors may help to delineate the role of sodium in intestinal calcium transport. Accordingly, the influence of ethacrynic acid and ouabain on rat intestinal calcium transport was investigated. Ethacrynic acid inhibited net water and calcium flux across the intestine. Ouabain, however, inhibited water flux without concomitant inhibition of intestinal calcium transport. By fractionation of the mucosal cell, a phosphatase that is dependent on calcium and sodium was identified and localized to the plasma membrane at the base of the mucosal cell. This enzyme activity was also inhibited by ethacrynic acid but not by ouabain. The data suggest that this enzyme may mediate intestinal calcium transport and that sodium is required in the activation of this enzyme.

Calcium transport was studied with the use of everted 3.0-cm duodenal and ileal gut sacs prepared from Wistar rats (4 weeks old), by the method of Wilson and Wiseman (*7*). The animals were maintained on calcium-deficient diets for 5 days before they were killed. The incubation medium contained 140 m*M* NaCl, 0.4 m*M* $CaCl_2$, 2 m*M* glucose, and calcium-45 (0.02 μc/ml) in 4 m*M* phosphate buffer; final *p*H was 7.4. The everted sacs were filled with 0.15 ml of medium that contained the appropriate inhibitor of sodium transport. Ethacrynic acid (*8*) and ouabain (Sigma) were studied at concentrations from 0.1 to 1 m*M*. The intestinal sac preparations were incubated for 50 minutes at 37°C. Water is not actively transported by the intestine, and net water flux is totally dependent on net sodium transport (*9*). Accordingly, net water flux from the mucosal to the serosal side was used as an indicator of net sodium flux. Net water flux was determined gravimetrically as the gain in weight of the intestinal sac during incubation. The accumulation of calcium-45 in the fluid bathing the mucosal surface was also measured. Calcium transport was derived from the difference between the disintegrations per minute in the final sac content and this value in the initial sac content.

Ethacrynic acid inhibited calcium-45 transport and, to a lesser extent, net water flux in the everted duodenal and ileal sacs (Table 1). Ouabain inhibited net water flux in the ileum and, at higher concentrations (1 m*M*), it inhibited net water flux in the duodenum. Although the inhibition of water or sodium flux by ouabain was greater than that by ethacrynic acid, calcium transport was not inhibited by ouabain. Thus, under certain experimental conditions calcium transport may be independent of net water and sodium flux.

Calcium transport across the red cell membrane may be mediated by a calcium-activated, Mg-dependent adenosine triphosphatase localized in the red cell membrane (*10*). We proposed that a similar enzyme, dependent on calcium, exists in the mucosal cell membrane. Two additional constraints were imposed on the proposed enzyme complex: it would be activated by sodium and be localized on the serosal side of the mucosal cell. The movement of calcium across the luminal or brush border surface does not require sodium in the extracellular fluid (*1*) and is not the rate limiting, energy-dependent step in calcium uptake (*2*, *3*). Accordingly, we sought to identify an enzyme activity that is associated with the plasma membrane of lateral and basilar portions of the intestinal mucosal cell and that requires both sodium and calcium for activity and uses adenosine triphosphate (ATP) as a substrate.

The differentiation of the luminal and basal or serosal surfaces of the mucosal cell with respect to structure and function permits the isolation and separation of the respective plasma membranes. The brush border fraction (BB) of the luminal surface of the cell was prepared by the method of Forstner *et al.* (*11*). Fraction BM, consisting of lateral and basilar plasma membrane fragments that were relatively free of brush border fragments and mitochondria, was prepared by the method of Quigley and Gotterer (*12*) with the use of a discontinuous sucrose gradient. Each preparation was characterized by assay of the marker enzymes β-fructofuranosidase (E.C. 3.2.1.26) (*13*) and Na, K–activated, Mg-dependent adenosine triphosphatase (E.C. 3.6.1.3), which is subsequently referred to as Mg–adenosine triphosphatase (*14*). The former is localized exclusively in the BB fraction, which is devoid of the latter enzyme (*12*, *15*). Mitochondrial contamination was estimated by cytochrome oxidase activity (*16*). By these criteria, the BM fraction was contaminated with brush border fragments and mitochondria. However, the specific activity of β-fructofuranosidase in the BM fraction was less than 27 percent of that in the BB fraction, and the specific activity of cytochrome oxidase in the BM fraction was less than 5 percent of that in the mitochondrial fraction.

In the absence of magnesium, 4 m*M* calcium stimulated ATP hydrolysis in both the BB and BM fractions (Table 2). With 120 m*M* sodium as the only cation, there was very little ATP hydrolysis. Phosphatase activity in the presence of both sodium and calcium was compared to that with calcium alone; activity was enhanced in the BM fraction but inhibited in the BB and mitochondrial fractions. Thus, the major contaminants of this BM fraction —brush border fragments and mitochondria—would not contribute to the activity stimulated by sodium and calcium.

The response of this phosphatase to the inhibitors studied in the intestinal sac preparations was investigated. As for calcium transport in the intact tissue, this enzyme was inhibited by ethacrynic acid but not ouabain. In contrast, the activity of Mg–adenosine triphosphatase was inhibited by ouabain and to a lesser extent by ethacrynic acid, a result consistent with those for different tissues (*6*, *17*). Phosphate esters other than ATP can serve as substrates for the enzyme dependent on sodium and calcium.

The Mg–adenosine triphosphatase enzyme system presumably mediates the pumping of sodium out of the mucosal cell, as it does in other cell systems. This results in an electrochemical gradient across the brush border. This gradient would facilitate uptake of calcium by the cell. However, the failure of ouabain to inhibit net calcium transport at concentrations that inhibit this Mg–adenosine triphosphatase activity and also inhibit net water transport suggests that this downhill electrochemical gradient for calcium ion across the brush border is not the rate-limiting step in calcium transport. Similarly, it has been suggested by others that this same gradient, sustained by the Mg–adenosine triphosphatase system, facilitates the extrusion of calcium in exchange for sodium, which passively reenters the cell along the favorable sodium gradient (*3*). Ouabain inhibition of the Mg–adenosine triphosphatase would also abolish this transport mechanism at the serosal surface of the cell. In addition, ouabain inhibited net flux of sodium from the mucosal to the serosal side, an effect that may be independent of those on the Mg–adenosine triphosphatase (*6*).

Finally, at the sodium concentrations in mucosal medium at which calcium transport is maximal, net sodium transport is reduced to zero (*18*). As mucosal sodium concentration is increased, transport of sodium and water is enhanced and calcium transport is inhibited. These data suggest that calcium transport is independent of both bulk water flow and net sodium transport. This apparent independence of calcium transport from both the sodium-potassium exchange pump and net sodium transport suggests that the transport process for calcium is mediated by a specific enzyme system. The phosphatase dependent on sodium and calcium, which was isolated from the basal membrane, was sensitive to ethacrynic acid but not to ouabain, a result consistent with the response of these inhibitors of calcium transport in

Table 1. Effect of ethacrynic acid and ouabain on calcium and water transport in rat intestine. Fluxes from the mucosal to the serosal side were studied in everted intestinal sacs incubated at 37°C for 90 minutes. The effect of the inhibitor on calcium transport, measured as nanomoles of calcium accumulated by the everted intestinal sac per hour, is expressed both as the difference (Diff.) and as the percentage of change from the control (incubated without inhibitor). The net water flux, measured as the net accumulation of water by the intestinal sac, is expressed similarly. The standard error (S.E.) of the difference is given. Except where indicated, all values differed significantly ($P < .05$) from controls.

Tissue	Inhibitor							
	Ethacrynic acid				Ouabain			
	0.5 m*M*		0.1 m*M*		1.0 m*M*		0.5 m*M*	
	Diff. ± S.E.	Percent	Diff. ± S.E.	Percent	Diff. ± S.E.	Percent	Diff. ± S.E.	Percent
	Calcium transport (nmole/hour)							
Duodenum	−2322 ±869	−51.7	−920 ±623	−20.1	−260* ±521	− 6.8	+314* ±577	+ 5.6
Ileum	−425 ±219	−48.7	−406 ±183	−52.8	+225* ±146	+29.1	− 11* ±116	− 1.2
	Water transport (μl/g)							
Duodenum	−28.9 ±18.2	− 5.2	− 9.3* −12.5	− 0.8	− 73.9 ± 15.0	−23.2	− 20.3* ± 38.8	− 4.6
Ileum	−40.7 ±36.0	−18.1	−27.5 ±12.2	−10.1	−249.3 ± 55.5	−37.8	−146.5 ± 50.3	−32.9

* $P \geq .5$.

Table 2. Adenosine tryphosphatase activity in brush border (BB) and basilar membrane (BM) fractions. Enzyme activity is expressed as micromoles of inorganic phosphate produced per milligram of protein in 10 minutes. Assays were done in 60 m*M* imidazole-histidine buffer, *p*H 7.4. The substrate, the tris(hydroxymethyl)aminomethane salt of ATP, was used at a concentration of 4 m*M*. Other concentrations were ethacrynic acid (EA), 1.0 m*M*; ouabain (Oua.), 1.0 m*M*; Na^+, 120 m*M*; Ca^{2+}, 4 m*M*; Mg^{2+}, 4 m*M*; K^+, 15 m*M*.

Additions	Enzyme activity in:	
	BB (mean ± S.E.)	BM (mean ± S.E.)
None	0.08 ± 0.02	0.05 ± 0.02
Na^+	0.06 ± 0.03	0.08 ± 0.03
Ca^{2+}	0.52 ± 0.02	0.65 ± 0.02
Ca^{2+}, Na^+	0.36 ± 0.02	0.95 ± 0.03
Ca^{2+}, Na^+, EA	0.34 ± 0.04	0.71 ± 0.03
Ca^{2+}, Na^+, Oua.	0.38 ± 0.04	0.97 ± 0.03
Mg^{2+}	0.56 ± 0.03	0.60 ± 0.04
Mg^{2+}, Na^+, K^+	0.82 ± 0.02	1.80 ± 0.02
Mg^{2+}, Na^+, K^+, EA	0.77 ± 0.03	1.50 ± 0.03
Mg^{2+}, Na^+, K^+, Oua.	0.64 ± 0.02	0.82 ± 0.03

the intact cell. Although further characterization of this enzyme is necessary, these observations are consistent with the interpretation that this phosphatase is a part of a specific enzyme system that mediates the energy-dependent translocation of calcium across the plasma membrane at the serosal surface of the mucosal cell. Therefore, the role of sodium in intestinal calcium transport may be the activation of this enzyme system.

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The Immune Reaction as a Stimulator of Tumor Growth

Abstract. *Various numbers of spleen cells from specifically immunized mice were mixed with constant numbers of target tumor cells, and were inoculated subcutaneously into thymectomized, x-irradiated recipients. Small numbers of admixed immune spleen cells produced a statistically significant, and reproducible, acceleration of tumor growth in the inoculum as compared with controls of either nonimmune spleen cells or spleen cells from animals immune to a different, noncross-reacting, tumor. Larger numbers of specifically immune spleen cells, however, produced inhibition of tumor growth. These data imply that the normal immune reaction may have a dual function in relation to neoplasia: (i) stimulation of tumor growth, early in the course of the disease, or whenever the immune reaction is minimal; (ii) inhibition of tumor growth at other times.*

I recently advanced the theory that the effect of immunity on target tumor cells might be biphasic, that is, a mild reaction might stimulate tumor growth although a strong one is cytotoxic (*1*, *2*). This theory is based primarily on the considerable data suggesting that, under some circumstances, a slight degree of immune reactivity may benefit fetal growth and survival (*2*). Since a fetus and a tumor share the quality of being antigenically foreign to their hosts, tumor growth might likewise be stimulated by a mild immune reaction. The mechanisms by which the immune reaction might actually stimulate tumor growth are open to speculation, but a clue is provided by the report that small concentrations of lymphotoxin are stimulatory, rather than cytotoxic, to target cells (*3*).

The theory was tested with Winn procedures (*4*), that is, varying numbers of immune spleen cells were mixed with tumor cells and the effect on the tumor was assayed by inoculating the mixtures subcutaneously into test mice. The tumors were sarcomas that had been induced by treatment of inbred DBA/2 or F_1 hybrid mice [($C_{57}BL \times BALB/c$) and ($C_{57}BL \times C_3H$)] with 3-methylcholanthrene. The tumor cells were suspended in modified Eagle tissue culture medium by the action of Pronase and deoxyribonuclease. The live cells were counted after they were stained with trypan blue, and a small number (usually 10^4) were mixed with graded numbers of immune or nonimmune, syngeneic, spleen cells. The tumors were in the first to fifth transplant generation when they were used. Because the different tumors varied in their growth rates, the time selected for analysis of the data varied slightly among experiments but it was always when the diameter of the largest tumor most nearly approximated 10 mm.

The syngeneic recipients had been previously thymectomized as adults and then, 24 hours before inoculation of the mixtures of tumor and spleen cells, had been given 450 roentgens of total body x-irradiation. This regimen of thymectomy and x-irradiation crippled the capacity of the mouse to reject a primary skin allograft. Therefore, the effects of the admixed spleen cells on the growth of the inoculated tumors were probably not complicated by host immunity.

The donors of immune spleen cells were syngeneic mice that had grown the particular tumor for 10 to 20 days. Usually the tumors were excised and the spleens were harvested 7 to 12 days after excision. In one experiment, however, spleens were harvested without prior excision of the immunizing tumors.

Initially, there were five experiments with three tumors that were induced separately. Experimental and control recipients were paired for inoculation. Control spleen cells were obtained from nonimmunized donors in four of the five experiments. In the other experiment, the control spleen cells were obtained from mice that had been immunized in the standard manner against a different, and noncross-reacting, tumor.

The results of this first series of experiments are presented in Fig. 1. It became apparent that tumor growth was accelerated when normal syngeneic spleen cells were mixed with the tumor cells as compared with that when no spleen cells were present. A similar finding has been reported by Deckers *et al.* (*5*). In addition, in my experiments, the immune spleen cells produced an even greater acceleration than did the control spleen cells when, and only when, these immune cells were added in amounts of less than 10^5, that is,

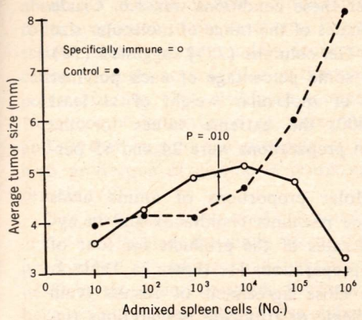

Fig. 1. Results of an initial series of five experiments. The curves have been smoothed by averaging: that is, the plot for ten spleen cells is actually the average of the values for 0, 10, and 10^2; that for 10^2 is the average of 10, 10^2, and 10^3, and so forth. There were 13 to 37 observations per point.

when they were approximately equal to, or less than, the number of tumor cells. At higher proportions of spleen cells, those from the specifically immune donors produced an inhibition of tumor growth.

The acceleration of tumor growth in these experiments (as measured by greater tumor size) with 10^3 or 10^4 specifically immune spleen cells was statistically significant (the paired sign test). Thirty-six of the 54 unequal pairs available had the largest tumor with the admixed immune spleen cells [$P = .010$ (one-tail distribution)]. Only one of the individual experiments was large enough to yield statistically significant results, although the data of each, with one exception, pointed in the same direction. The one experiment in which the data did not show this trend was the experiment in which the "immune" spleen cells had been obtained from donors bearing unexcised tumors. There are reports that such cells may lack cytotoxic activity in vitro in the colony inhibition assay. However, the possible influence of this factor in the present type of experiment is yet to be determined (*6*–*8*).

These initial results were then confirmed in an experiment with one of the tumors used in the previous series. The experimental method was substantially the same as before except that only three amounts of spleen cells were used: 0, 5×10^4, and 10^7. The groups were somewhat larger in an attempt to achieve a statistically significant result within the data of the single experiment. Also, a second control group was added in which the spleen cells were obtained from animals that had been immunized against a different, and noncross-reacting, tumor.

The results of the confirmatory experiment are presented in Fig. 2. With 5×10^4 spleen cells, there was better tumor growth in the specifically immune spleen cell group. There was no apparent difference between the groups receiving the nonspecifically immune cells and those that received the normal spleen cells. A statistical analysis of the specifically immune as compared to the nonspecifically immune spleen cell group, by the paired sign test, gave $P = .002$ (one-tailed test). When compared to the groups that received nonimmune spleen cells, the value was $P = .035$. The combined value was $P < .001$. The results of this experiment thus confirmed the relative stimulation of tumor growth by a low dosage of immune spleen cells.

Prior immunization can lead to accelerated growth of subsequent tumor implants, the phenomenon commonly called "tumor enhancement." This effect can be transferred by passage of immune lymphoid cells (*9*); a biphasic reaction has also been reported (*10*). However, this acceleration has only been described in comparison with growth in nonimmunized, but immunologically competent, controls and is generally ascribed to the formation of blocking antibodies or immune complexes. In contrast with the usual type of enhancement, the tumor acceleration that I have reported here involved recipient animals that had been thymectomized and then exposed to 450 roentgens of x-irradiation 24 hours prior to tumor implantation. Thus, the accelerated tumor growth observed in my experiment is probably not explainable on the basis of a blockage of recipient immunity. However, there is a possibility that the sensitized spleen cells of the inoculum produced blocking factors that interfered with further stimulation of the inoculated immune spleen cells themselves, or with the sensitization of previously nonsensitized portions of the "immune" inoculum.

Whatever the mechanism may be, my experiments show that normal syngeneic spleen cells in contact with a tumor can stimulate tumor growth and that, if these spleen cells were specifically sensitized, they stimulated growth even more provided that a critical dosage level is not exceeded.

There may be a time, in the early evolution of tumors, when the immune

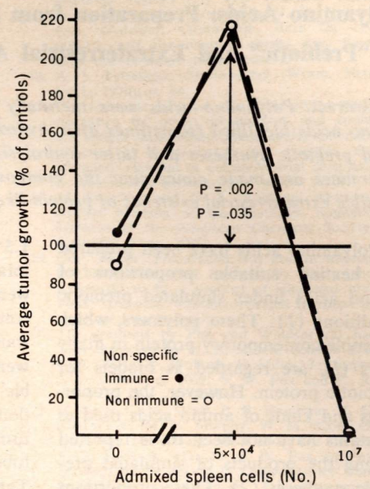

Fig. 2. Results of the confirmatory experiment. The two plots represent the growth of the same series of tumors as compared with two different types of control: controls with normal spleen cells and controls with nonspecifically immune spleen cells, that is, spleen cells from animals immune to a different, and noncross-reactive, tumor. There were 5 to 13 observations per point.

response is incipient and therefore weak. If this situation is comparable to a low dosage of immune spleen cells, the normal immune reaction may actually assist the growth of nascent tumors. Furthermore, if a weak immunity stimulates tumor growth, immunoselection by the growth-stimulatory immune reaction would provide an explanation of the fact that most, and perhaps all, tumors are antigenic.

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Polyamino Acids: Preparation from Reported Proportions of "Prebiotic" and Extraterrestrial Amino Acids

Abstract. *Polyamino acids were thermally prepared from the proportions of amino acids identified (sometimes after hydrolysis) among the products of simulated prebiotic syntheses and (after hydrolysis) in lunar and meteoritic samples. Inferences are made concerning the composition of prebiotic protein and the possible extraterrestrial existence of protein-like polymers.*

Polyamino acids have been prepared by heating suitable proportions of amino acids under simulated prebiotic conditions (*1*). These polymers, which resemble contemporary protein in many ways (*1*), are regarded as models for prebiotic protein. However, the proportions and kinds of amino acids used as reactants have not been those reported among the products of simulated prebiotic syntheses (*2*). These proportions of amino acids [including nonproteinous amino acids (*3*)] may have influenced the composition of primitive protein. We therefore used as reactants the exact proportions of amino acids found in the products (sometimes after hydrolysis) of five "prebiotic" syntheses (*4–8*) and also those reported as constituents (after hydrolysis) of two lunar samples (*9*) and of the Murchison meteorite (*10*).

The amino acid mixtures (5.1 to 8.7 g) were polymerized (*1*) at 175°C under a stream of nitrogen gas for a period of 1.5 to 6 hours. The products, largely or totally soluble in water or in dilute base, were dialyzed for 48 hours against a continual flow of distilled, deionized water, and the nondiffusible portions were then lyophilized after any insoluble materials were removed by filtration. Portions of the polymers were hydrolyzed in 6*N* HCl, under N_2 in sealed tubes, at 109° to 110°C, 48 to 53 hours. The hydrolyzates were analyzed with an amino acid analyzer (Beckman model 120C) (*11*); norleucine was used as an internal standard.

We obtained polymeric material from all reactants tested, in yields of 0.3 to 5.7 percent by weight. Each polymer contained peptide bonds, as indicated (*12*) by absorbance peaks at 1650 (amide I), 1550 (amide II), and 3300 cm^{-1} (amide A), and also by positive biuret reaction. Biuret color intensities ranged from 0.9 to 1.7 absorbance units per gram of polymer per liter; the value obtained for crystalline bovine albumin under these conditions was 1.6. Crude estimates of the range of molecular size [Bio-Gel columns (*13*)] suggested (*14*) that some percentage of each polymer was of molecular weight of at least 10,000; the extreme values for the eight preparations were 24 and 65 percent.

Table 1. Amino acid compositions of the reactants (boldface numerals) and of the dialyzed products of four thermal preparations. The reactants were patterned according to the proportions of amino acids reported in the indicated references. Duplicate or triplicate entries result from duplicate or triplicate syntheses. The compositions are expressed to three figures to show the presence of minor constituents (< 1 percent) and to indicate the reproducibility of the syntheses; accuracy to three figures is not implied. Dashes, not present in reactants or products; tr, trace.

Amino acid	Amino acid composition (moles per 1000 moles of amino acids)											
	Miller* (*4*)		Fox* (*5*)		Lunar A (*9*)				Meteorite* (*10*)			
Glycine	**506**	430	**571**	691	**555**	693	691	687	**360**	535	532	
Alanine	**273**	194	**91**	119	**142**	119	120	129	**174**	155	154	
Aspartic acid	**3**	7	**103**	128	**129**	129	128	119	**57**	68	54	
Glutamic acid	**5**	53	—	—	**46**	30	28	28	**94**	40	46	
Leucine	—	—	**39**	17	—	—	—	—	—	—	—	
Threonine†	0	2	**0**	8	**31**	9	9	10	**0**	1	3	
Serine†	**0**	3	**79**	4	**98**	10	8	11	**0**	2	3	
Isoleucine	—	—	**0**	1	—	—	—	—	—	—	—	
Proline	—	—	—	—	—	—	—	—	**50**	24	27	
Valine	—	—	**117**	28	—	—	—	—	**61**	48	61	
β-Alanine	**120**	202	—	—	—	—	—	—	**20**	34	29	
α-Amino-*n*-butyric acid	**40**	51	**0**	5†	**0**	11†	10†	11†	**47**	46	46	
α-Aminoiso-butyric acid	**4**	0	—	—	—	—	—	—	**107**	0	0	
β-Aminoiso-butyric acid	—	—	—	—	—	—	—	—	**30**	44	43	
Sarcosine	**40**	22	—	—	—	—	—	—	—	—	—	
N-Methylalanine	**8**	33	—	—	—	—	—	—	—	—	—	
Unknowns‡	**0**	2	—	—	**0**	tr	5	5	**0**	3	3	

* Only those amino acids quantified in literature reports were included in our reactants. † Identification tentative. ‡ Calculated assuming a norleucine color equivalent of 1.000.

Molar proportions of amino acids in the reactants (boldface) and in hydrolyzates of the products for four of the preparations are shown in Table 1. The close agreement of results from duplicate or triplicate preparations (including three not shown in Table 1) indicates that these polymerizations, as others (*1*), are reproducible. In each preparation, some amount of each amino acid present in the reactants was found in the hydrolyzate of the polymer, except for α-aminoisobutyric acid (*15*) and, possibly, serine and threonine (*15*). To what extent, if any, dicarboxylic amino acids were present as amides was not determined. Minor amounts of unknown compounds (Table 1) were found in hydrolyzates of most preparations; nascent α-amino-*n*-butyric acid was tentatively identified in three cases.

Glycine was the predominant constituent of all but one [that patterned according to (*8*)] of our reactants and of all products. Alanine in most cases was the second most common amino acid present. Large proportions of these amino acids are not common in contemporary protein with the exception of some structural protein [for example, fibroin, elastin, collagen (*16*)]. In addition, nonproteinous amino acids (*3*), when present in the reactants, were found in the products. These results suggest that, if the proportions of amino acids used as reactants are representative of those of abiotic environments (*17*), prebiotic protein may have been rich in glycine and alanine and may have contained nonproteinous amino acids. The stage (or stages) of evolution at which nonproteinous amino acids may have been selected against has yet to be resolved (*18*).

Our "Sagan" preparation (*8*) was of particular interest in that our reactants contained only 9 percent glycine (and 86 percent alanine), whereas the dialyzed product contained 59 percent glycine (and only 30 percent alanine). The enrichment with glycine of the nondiffusible portion of the preparation was probably due to preferential incorporation of glycine, rather than to the decomposition of alanine, because the crude (undialyzed) product contained about 92 percent alanine, comparable to its proportion in the reactants. These results indicate a nonrandom incorporation of amino acids (*1*) during thermal polymerization (less strikingly evident from compositions listed in Table 1) and further suggest the presence of a high proportion of glycine in primitive protein (*19*).

Our study has shown that polyamino acids are formed thermally from the proportions of amino acids obtained (*4–8*) by the action of spark discharge, heat, or ultraviolet light on five different geologically plausible atmospheres or hydrospheres. These findings are interpreted to support a proposed molecular evolutionary continuum (*5*), from primitive gases to amino acids to polyamino acids. Our "Miller" and "Sagan" preparations are perhaps the more pertinent in this context, because their syntheses (*4, 8*) apparently yielded free amino acids. However, our "Fox" preparation is also of interest in that the amino acids were obtained [after hydrolysis (*5*)] not from primitive atmospheres of conjectural composition (*1*), but from identified constituents of interstellar space (*20*). Fox and Windsor (*5*) indicate that free amino acids could result naturally from their product [which possibly was hexamethylenetetramine (*20*) and not a polyamino acid (*5*)], and they implicate such amino acids in the evolutionary sequence: ". . . simple compounds → amino acids → proteinoids [polyamino acids] → microspheres. . . ." Our results show that polyamino acids are formed from their reported proportion of amino acids.

The uncertainties concerning the compositions of primitive atmospheres also do not apply to our "meteorite" and "lunar" preparations. The amino acids we used, however, were those quantified after the hydrolysis of samples (*9, 10*). Although some free amino acids have been reported (*10, 21*), the indigenous lunar compounds probably (*22*) existed largely as (unidentified) precursors of amino acids. This study does indicate, however, that if the amino acids ever existed in free form, they could have polymerized thermally. The results, supported by evidence of a thermal lunar history (*23*), suggest that protein-like polymers could exist extraterrestrially.

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15. α-Aminoisobutyric acid was found in a "modified meteorite" poylmer (using one-fourth the glycine and four times the aspartic acid in the reactants). Materials eluting in the serine-threonine regions (*11*) were common. These amino acids are thermolabile [J. R. Vallentyne, *Geochim. Cosmochim. Acta* **28**, 157 (1964)], and the observed peaks may have been due to other compounds.
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Leukemia, Lymphoma, and Osteosarcoma Induced in the Syrian Golden Hamster by Simian Virus 40

Abstract. *Leukemia, lymphoma, and osteogenic and anaplastic sarcomas develop in Syrian golden hamsters inoculated intravenously at 3 weeks of age with simian virus 40, which is a popova virus. Previously, only RNA and herpes DNA viruses have been recognized as capable of inducing leukemia and lymphoma in mammals. The significance of these findings is emphasized in relation to the nature of viral agents that may be involved in analogous diseases of man.*

Avian and murine leukemia and lymphoma are induced by a number of closely related RNA viruses (*1*). However, oncogenic DNA viruses, except those that belong to the herpes group (*2, 3*), have not been shown to possess leukemogenic or lymphomagenic properties. Various workers, therefore, have proposed that RNA viruses will most likely prove to be etiologically associated with the analogous diseases in man. Since this view is based only on negative evidence (*4*), the question of whether a DNA virus of known oncogenic potential other than a member of the herpes group, could induce, under appropriate conditions, leukemia or lymphoma in the experimental animal was investigated. The weanling rather than the newborn Syrian golden hamster and the known oncogenic agent simian virus 40 (SV40), a DNA virus that belongs to the papova (*5*) group, were used.

In this experiment, 300 weanling male Syrian hamsters, 21 to 22 days old, with an average weight of 44 g (range 35 to 55 g; 83 percent weighed 40 to 50 g) were used. Of these, 250 were inoculated via the femoral vein and 50 were held as uninoculated controls. The animals that were inoculated intravenously were divided into four groups (Table 1). Each of 100 received $10^{8.5}$ median tissue culture infective doses ($TCID_{50}$) of SV40 stock virus, strain VA 45-54 (*6*), suspended in 1 ml of culture medium. Each of 50 animals

Table 1. Tumor incidence in hamsters receiving SV40 or SV40 plus specific antiserum. The animals were inoculated intravenously. NRS, normal rabbit serum.

Hamsters (No.)	Inoculum	Tumors (%)
100	SV40	84
50	SV40 + antiserum to SV40	0
50	SV40 + NRS	94
50	Culture medium	0
50	None	0

received 2 ml of a mixture consisting of equal parts of SV40 virus suspension ($10^{8.5}$ $TCID_{50}$/ml) and of undiluted rabbit antiserum to SV40 virus (*7*). Each of 50 received 2 ml of a mixture of equal amounts of SV40 of the same infective titer and of normal rabbit serum (*7*). The remaining 50 animals were each inoculated with 1 ml of culture medium. This medium was prepared from the same components used in the production of the SV40 stock virus in grivet monkey kidney (GMK) cell cultures. It had not been in contact with cells.

Animals were examined (under ether anesthesia) at weekly intervals for tumors. The first tumors were detected 4 months after the experiments were begun. In the groups inoculated with SV40 or SV40 plus normal rabbit serum, the incidence of tumors reached a peak during the fifth month. At this time many of the animals bearing tumors were killed and necropsied. By the end of the 6th month, when all surviving animals were likewise necropsied, the overall tumor incidence was 84 percent in the former and 94 percent in the latter group (Table 1). In the remaining 150 hamsters no tumors were detected either during life or at the time the animals were necropsied at 6 months. These animals included 50 that were inoculated intravenously with the mixture of SV40 and rabbit antiserum to SV40, 50 that received culture medium, and 50 that were held as uninoculated controls (Table 1).

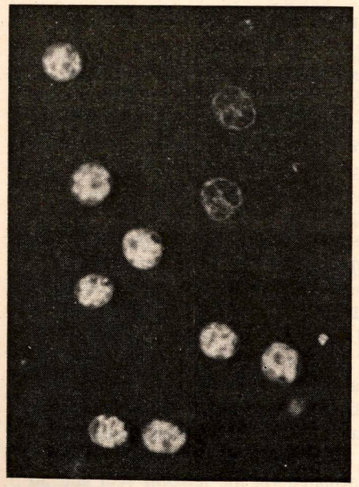

Fig. 1. Peripheral blood smear of a hamster bearing SV40-induced lymphocytic leukemia. The white (reacting) nuclei of the leukemic lymphocytes have been stained by indirect immunofluorescence for the SV40-mediated T ("tumor") antigen. Two normal polymorphonuclear leukocytes are shown with nonreacting nuclei. The erythrocytes are faintly visible; scale 10 μm.

One of the 125 animals with neoplasm had lymphocytic leukemia (Fig. 1), characterized by an elevated peripheral blood leukocyte count (125,000 per cubic millimeter). The leukemic process involved primarily bone marrow, superficial lymph nodes (cervical, axillary, inguinal), spleen, liver, and, to a lesser extent, deep lymph nodes (mediastinal, mesenteric), lungs, intestine, and kidneys. The thymus was intact. Five animals had malignant lymphoma—that is, lymphosarcoma—involving predominantly superficial lymph nodes (Fig. 2) and, to a lesser degree, deep lymph nodes, spleen, and liver. The thymus was spared in all. In two of the five animals, lymphosarcoma cells were identified by indirect immunofluorescence staining for T ("tumor") antigen (*8*) and by the morphology of the cells in the peripheral blood, although no elevated leukocyte counts were recorded.

Of the tumor-bearing animals, 90 (72 percent) had neoplasm that involved mediastinal and mesenteric lymph nodes with frequent tumorous enlargement of the latter. In the majority of cases the liver, spleen, intestine, and Peyer's patches were also infiltrated by malignant cells. The histological features of these neoplasms were consistent either with malignant lymphoma—that is, reticulum cell sarcoma—or, with anaplastic sarcoma. In a large number of these animals, different sites of neoplastic growth or different areas of the same site exhibited slightly different morphology.

Of the tumor-bearing animals, 69 (55 percent) had osteosarcoma. In the majority of cases, the neoplasm arose from bones of the lower extremities. In a few, it arose from bones of the upper extremities or from the ribs. In 36 (52 percent) animals the tumor metastasized to the lungs. Although most of these neoplasms were apparently pure osteogenic sarcomas, some were mixed and consisted of osteosarcoma, spindle-cell sarcoma, and pleomorphic sarcoma. Five other animals had subcutaneous, poorly differentiated sarcoma. It is obvious from the foregoing data that as many as one-third of the animals with neoplasm bore more than one distinct histological type of malignant growth.

The failure of all animals receiving the mixture of virus and specific antiserum to develop tumors argues strongly for the etiological role of SV40 in the induction of the neoplasms found among the animals that had received the virus with or without normal rabbit serum. Additional immunological evidence supporting this conclusion is also provided by the identification of SV40 T antigen (*8*) in parenchymal cells of all 170 primary tumors examined (Figs. 1 and 2B) and by the demonstration of antibody against SV40 T antigen in the serums of a large number of adult hamsters that had received transplants of nine different tumors, representing five distinct morphological types—that is, one lymphocytic leukemia, two lymphosarcomas, two reticulum cell sarcomas, two anaplastic sarcomas, and two osteogenic sarcomas. Finally, since infectious SV40 was not recovered from the cells of two lymphosarcomas, three anaplastic sarcomas, and three osteosarcomas when grown in culture for 1 week in the absence of GMK indicator cells, it appears that the SV40 T antigen is not an expression of a recurrent infectious process, but rather, it is a manifestation of the oncogenic state.

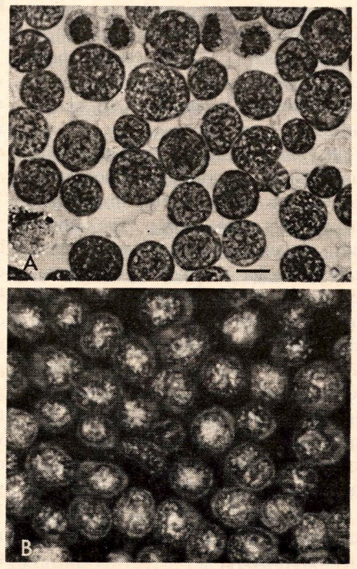

Fig. 2. Cervical lymph node imprints of an SV40-induced hamster lymphosarcoma. (A) Wright's-Giemsa stain; (B) fluorescent staining for SV40 T antigen; scale 10 μm.

The above data indicate that, under appropriate experimental conditions (*9*) relating both to the host (species, age) and to the viral agent (dosage, route of inoculation), the DNA virus SV40 can induce leukemia, lymphoma, and osteosarcoma in addition to the anaplastic sarcoma with which it is already known to be associated. These findings do not support the view held by some investigators that viruses which induce experimental leukemia, lymphoma, and osteosarcoma are always of the RNA type (*1, 10*). It should be of great interest, therefore, to determine whether other oncogenic DNA viruses (polyoma virus, adenoviruses) can induce, under comparable experimental conditions, hematopoietic, lymphoreticular, and osteomesenchymal malignant neoplasms. This may well prove to be the case, since evidence has been presented which suggests that polyoma virus may rarely cause osteosarcoma in the mouse (*11*), and that herpes DNA viruses can induce avian (*2*) and simian (*3*) lymphomatous proliferations. Furthermore, there is some evidence suggesting that a herpes-type virus, the Epstein-Barr agent (*12*), may be related etiologically to Burkitt's lymphoma, a neoplasm that affects predominantly children living in Africa (*13*).

Although a decision on the issues raised should await the results of further inquiry, we can now state with assurance that, for the first time, a DNA virus other than a member of the herpes group has been implicated in the experimental induction of leukemia, lymphoma, and osteosarcoma. It is evident, therefore, that, in attempting to isolate and identify viral agents possibly involved in analogous diseases of man, attention should be directed toward DNA viruses.

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7. Antiserum to SV40 was derived from rabbits immunized with strain HDCS-DHK of SV40 (Pitman-Moore). It had a neutralization titer in vitro 1 : 1280, against 100 $TCID_{50}$ of SV40. Normal rabbit control serum failed when diluted 1 : 4 to neutralize 100 $TCID_{50}$ of SV40. Both types of serums were inactivated at 56°C for 30 minutes before use. The virus-serum mixtures were incubated at 37°C for 2 hours prior to inoculation. Both rabbit serums (VR-3002, VR-3000) were purchased from Grand Island Biological Co.
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Hormone-Calcium Interactions with the Plasma Membrane of Rat Liver Cells

Abstract. *The binding constants and the number of binding sites for insulin, glucagon, epinephrine, cyclic adenosine monophosphate, and calcium ions for the plasma membrane of rat liver were determined by Scatchard plots. The plots are biphasic or multiphasic, an indication of at least two types of binding sites for each ligand. At least three types of binding sites were found for insulin. In the concentration range of 10^{-6} to 10^{-8} molar, glucagon, epinephrine, and hydrocortisone increased calcium ion binding to the plasma membrane, whereas insulin decreased this binding. At hormone concentrations of 10^{-6} to 10^{-7} molar, glucagon was the most effective in increasing calcium binding, but at a hormone concentration of 10^{-8} molar, hydrocortisone was the most effective in stimulating calcium binding. Adenosine triphosphate reversed the effect of insulin and inhibited the effect of the other hormones. These studies suggest a relation between hormones and calcium with respect to membrane structure and function.*

Certain hormones, such as glucagon, epinephrine, and insulin, probably exert at least part of their physiological effects at the level of the cell plasma membrane (*1–4*). Rasmussen (*5*) has proposed a model to integrate the relation between hormone, calcium ion, and cyclic adenosine monophosphate (cyclic AMP). In this model, certain hormones act to stimulate the membrane-bound adenylate cyclase that produces cyclic AMP from adenosine triphosphate (ATP). The cyclic AMP then activates protein kinases in the cytoplasm which, in turn, phosphorylate several enzymes or contractile proteins within the cell to modulate the activities of these macromolecules. A second controlling influence in the cell is postulated to be the calcium ion (Ca^{2+}). The mobilization of calcium from intracellular pools, or its influx from extracellular fluid, are thought to occur by hormonal or electrical stimulation of the cell plasma membrane or by an action of cyclic AMP on intracellular membranes. The increased intracellular concentration of Ca^{2+} may induce other enzyme reactions within the cell, or it may act as a negative feedback control on adenylate cyclase. Calcium pumps are also considered to play a role in the active efflux of calcium from the cell. Rasmussen (*5*) suggests

that certain hormones interact with their receptors in the membrane to simultaneously increase calcium permeability and adenylate cyclase activation as has been shown in many experiments in which excitation of cells is followed by a rise in concentration of cyclic AMP. In some systems this rise is accompanied by an increased uptake of Ca^{2+} into the cell or a requirement for Ca^{2+} in the external medium.

Hormones may have more than one action on cell membranes. They may activate membrane-bound adenylate cyclase, as has been demonstrated in isolated plasma membranes from liver (*6–10*), and in isolated fat cells (*11*). The effect of insulin on glucose transport in muscle and fat cells is well established (*1–4*). However, insulin does not penetrate the fat cell (*12*) yet it produces other effects in the cell which are independent of glucose transport. Apparently, insulin has at least two independent actions on fat cells.

The binding of insulin, glucagon, and epinephrine to isolated plasma membranes of the rat liver or to isolated fat cells has recently been reported (*6, 9, 13–22*). We demonstrate here that hormones bind to plasma membranes and can influence the binding of Ca^{2+} to isolated plasma membranes. These effects are independent of the adenylate cyclase system, and they suggest a relation between potentially important hormones and calcium with respect to membrane structure and function.

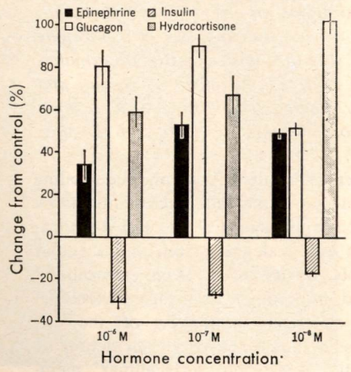

Fig. 1. The effect of hormones on the binding of calcium ions to the plasma membrane. Membranes (60 to 70 μg of protein) were incubated with 0.001*M* $CaCl_2$ (containing 0.5 μc of ^{45}Ca) for 10 minutes at 37°C in a total volume of 1.0 ml containing 0.1*M* tris buffer, *p*H 7.5, and varying amounts of hormone. The binding of ^{45}Ca was determined as described in Table 1.

Plasma membranes of rat liver were prepared by the method of Ray (*23*) and washed with ethylenediaminetetraacetate (EDTA) and 50 m*M* tris(hydroxymethyl)aminomethane (*p*H 7.4) before use. The [^{131}I]insulin (Insulin 131-H Imusay, specific activity, 287 mc/mg; Abbott) was purified by column chromatography on Sephadex G-10; this labeled insulin contains less than 1 atom of iodine per insulin molecule. The [^{125}I]insulin (specific activity, 110 mc/mg) with 1 atom of iodine per insulin molecule was prepared by the method of Izzo *et al.* (*24*). The [^{131}I]-glucagon (specific activity, 114 mc/mg) (*25*) contained approximately 1 atom of iodine per molecule of glucagon, and was homogeneous after Sephadex G-10 chromatography. The specific activities of other labeled hormones used is as follows: DL-7-[^{3}H]epinephrine, 7 to 14 c/mmole (New England Nuclear); $^{45}CaCl_2$, 6 mc per milligram of calcium (I.C.N.); [^{3}H]cyclic AMP, 24 c/mmole (New England Nuclear). The hydrocortisone was unlabeled (Nutritional Biochemical). Protein was determined, throughout the experiments, by the method of Lowry *et al.* (*26*).

Scatchard plots (*27*) of the bound hormones, cyclic AMP, and calcium were used to determine the binding constants and the number of binding sites per milligram of membrane protein. The results of these analyses are shown in Table 1. All plots were biphasic, an indication of at least two types of binding sites. The high affinity sites are believed to represent the physiologically important sites. The low affinity sites probably represent nonspecific binding. The lowest hormone concentration was that for insulin (10^{-9} to $10^{-11}M$). The high affinity site was saturated at about $10^{-9}M$ insulin and had a binding constant of $10^{10}\,M^{-1}$. A dissociation constant of $6.7 \times 10^{-11}M$ has been calculated for insulin binding to crude liver membranes (*19*).

The binding constants for cyclic AMP and calcium ions are much lower than those for the hormones, and the number of binding sites are much greater. This is not unexpected for calcium since Ca^{2+} can bind to a number of ionized anionic functional groups on the membrane (carboxyl and phosphate groups). The binding of cyclic AMP was weak and could not be observed by the Millipore filtration method.

The binding of calcium to isolated plasma membranes has the following characteristics (*28*): (i) an optimum *p*H of 7.8 to 7.9; (ii) saturation kinetics where equilibrium is attained after 10 to 20 minutes; (iii) a binding that is inhibited by EDTA and Mg^{2+} ions, but not by Na^{1+} or K^{1+}; (iv) a binding that is decreased by prior treatment of the membrane with Pronase, trypsin, neuraminidase, and phospholipase C, but increased by treatment of the membrane with phospholipase D.

The effect of hormones on binding of calcium to the membrane is shown in Fig. 1. Epinephrine, glucagon, and hydrocortisone at concentrations of 10^{-6} to $10^{-8}M$, increased Ca^{2+} binding whereas insulin decreased Ca^{2+} binding. At hormone concentrations of 10^{-6} to $10^{-7}M$, glucagon had the greatest effect, but at $10^{-8}M$, hydrocortisone exerted the greatest effect. Glucagon and epinephrine both stimulated binding most at $10^{-7}M$, but the stimulation by hydrocortisone increases with decreasing hormone concentration. With hydrocortisone, a hydrophobic hormone, the physical state of dispersion may influence its effect on the membrane.

Adenosine triphosphate at a concentration of 0.3 m*M* abolished the effect of insulin, and decreased the effect of the other hormones.

Inasmuch as the concentration of each hormone is very small, the hormone effects cannot be stoichiometrically related to the Ca^{2+} binding. In these systems we calculate that at $10^{-8}M$ hydrocortisone, one molecule of hormone leads to a binding of 3000 atoms of calcium. This postulates that the hormones act catalytically or that they induce conformational changes over a large segment of the membrane, modifying the binding of many calcium ions.

The effect of insulin opposite to that of the other hormones provides additional evidence for the antagonistic action of insulin with glucagon and epinephrine. Insulin antagonizes the glucagon stimulation of adenylate cyclase in isolated plasma membranes of rat liver (*8, 10*).

With respect to the model of Rasmussen (*5*), our studies suggest that the hormone effects on calcium binding may also be related to calcium transport through the membrane. We demonstrated that hormones such as glucagon, epinephrine, and insulin have two independent effects on the membrane, one being to either activate or inhibit adenylate cyclase activity, and the other being to stimulate or inhibit calcium binding. Although the concentration of hormones that is required to influence calcium binding is higher than the physiological concentration (insulin and glucagon have concentrations in portal blood of 10^{-9} to $10^{-10}M$), the effects may have physiological significance as the isolated membranes might have lower biological sensitivity than do membranes on intact cells.

Inasmuch as the amount of calcium bound to the membrane influences the permeability of the membrane, our studies also may suggest that certain hormones influence membrane permeability by controlling the amount of bound metal ions. Thus, insulin may make the cell membrane more permeable to certain substrates by decreasing the amount of bound calcium ions.

The significance of the ATP effect on modifying the calcium binding due to hormones is not clear. Whether this is related to the chelating property of ATP, to ATP altering the membrane structure, or indirectly to the cyclic AMP formed from ATP is not known. In the membrane systems we used, cyclic AMP is bound very weakly to the membrane and stimulates Ca^{2+} binding only at very high concentrations (10^{-3} to $10^{-5}M$) of cyclic AMP.

Table 1. Binding of glucagon, insulin, epinephrine, cycle AMP, and Ca^{+2} to the plasma membrane. Binding of glucagon and insulin was determined by incubating membranes (60 to 70 μg of protein) for 10 minutes at 37°C in 1 ml of 0.1*M* tris(hydroxymethyl)-aminomethane buffer (tris), *p*H 7.5. Glucagon (0.5 to 6.0 μc) was tested over the range 10^{-5} to $10^{-8}M$. Insulin (0.5 to 0.05 μc) was used from 10^{-5} to $10^{-11}M$. After 10 minutes, 2 ml of ice-cold 0.1*M* acetic acid were added, and the membranes were centrifuged at 2800 rev/min for 15 minutes. The supernatant was discarded, and the membrane pellet was washed twice with 2 ml of 0.1*M* acetic acid. The pellet was dissolved in 1 ml of solubilizer (NCS, Nuclear-Chicago), and was then diluted with 10 ml of Brays scintillation solution. The binding of epinephrine and calcium was determined by incubating membranes (60 to 70 μg of protein) for 10 minutes at 37°C in 1 ml of 0.1*M* tris buffer, *p*H 7.5. Epinephrine (0.6 μc) was tested at concentrations of 10^{-5} to $10^{-8}M$, and calcium (0.5 μc) was tested at concentrations of 10^{-3} to $10^{-7}M$. After 10 minutes, the membrane suspension was filtered through HA 0.45 μm Millipore filter disks (diameter, 25 mm), and washed two times with 5 ml of tris buffer. The filter disks were placed in counting vials containing 10 ml of Brays solution, and the radioactivity was measured (Packard liquid-scintillation spectrometer). Binding of cyclic AMP (10^{-4} to $10^{-8}M$, containing 0.01 μc of cyclic AMP) was measured by equilibrium dialysis as no binding was detected by the Millipore procedure. The K_2 for cyclic AMP was very small and is not included in the table.

Order	Association constant (M^{-1})		Binding sites (picomoles per milligram of membrane protein)
	Glucagon		
K_1	9.4×10^6	n_1	50
K_2	3.1×10^4	n_2	1300
	Insulin		
K_1	1×10^{10}	n_1	0.1
K_2	4.1×10^6	n_2	56
K_3	1.3×10^5	n_3	1270
	Epinephrine		
K_1	1.8×10^7	n_1	13
K_2	1.4×10^5	n_2	162
	Ca^{2+}		
K_1	4.0×10^3	n_1	22,000
K_2	3.1×10^2	n_2	126,000
	Cyclic AMP$^+$		
K_1	7.3×10^4	n_1	41,000

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Norepinephrine and Dopamine: Assay by Mass Fragmentography in the Picomole Range

Abstract. *Gas chromatography–mass spectrometry makes possible the simultaneous measurement of norepinephrine and dopamine in concentrations of 0.1-milligram tissue samples. Specificity of the assay is confirmed both by the retention time of the compound and by the mass to charge ratio of the fragments recorded. The sensitivity is of the order of 0.5 picomole, and linearity of the response is maintained up to at least 200 picomoles.*

A number of simple biochemical models of adrenergic neurons predict that small pools of catecholamines are preferentially released by nerve impulses (*1*). Since only circumstantial evidence supports this prediction, these pools must now be identified, characterized, and measured if these multicompartment models are to guide future investigation on the molecular nature of the mechanisms regulating adrenergic function.

These clarifications could be obtained if a method were available to measure femtomole (10^{-15} mole) concentrations of norepinephrine (NE) and dopamine (DA) in small samples of tissue. Accordingly, we have directed our attention to the analytical technique of combined gas chromatography (GC) and mass spectrometry (MS) (*2*). Identification of an unknown substance by MS usually requires at least 10^{-6} mole of a compound to record its fragmentation pattern and establish its identity. When the fragmentation pattern of the compound is known, it is then possible to identify as little as 3×10^{-15} mole of the substance by the technique of mass fragmentography

Table 1. The GC-MS characteristics of the PFP derivatives of norepinephrine, dopamine, and their α-methyl analogs. The minus sign indicates that the intensity was negligible.

PFP-amine derivative	GC retention time (min)	Relative intensity (%) at *m/e*: 176*	190*	428†	442†	590†	604†	Peak ratio
α-MNE	2.08	–	100	–	–	–	10	10
NE	2.83	100	–	–	–	40	–	2.5
α-MDA	4.36	–	100	–	33	–	–	3.3
DA	5.83	40	–	100	–	–	–	2.5

* Cleavage between the α- and β-carbon atoms. The positive charge is retained on the nitrogen-containing fragment. † Cleavage between the nitrogen and the α-carbon atom. The positive charge is retained on the fragment containing the aromatic ring and one hydrogen atom is transferred onto the neutral moiety.

(*3*), a technique in which the mass spectrometer is used as a detector for the gas chromatograph. In this way the GC separates the compounds prior to MS analysis, and the GC retention time gives one measure of specificity to the analysis. The MS gives more exact specificity by measuring two or more abundant characteristic fragments (mass to charge, *m/e*) of the compound at its GC retention time. Our data show that it is possible to quantitate the ion density generated by these fragments, thereby providing an extremely sensitive and specific analytical method.

In our method, mass fragmentography is used to quantitatively assay NE and DA in tissue. For this quantitative assay, the choice of the internal standard is important. Ideally, the internal standard should be the same compound labeled with stable isotopes in a group included in each of the two fragments selected for the analysis (*4*). Since, at present, the availability of compounds labeled with stable isotopes is rather limited, we have used α-methylnorepinephrine (α-MNE) and α-methyldopamine (α-MDA) as internal standards for NE and DA, respectively. These internal standards allow for normalization of the data for losses due to sample manipulations and for fulfilling all the other requirements of a suitable internal standard.

In developing our method, the first problem we had to solve was that of forming volatile, stable derivatives of the four catecholamines. By reacting the four catecholamines with pentafluoropropionic anhydride (PFPA; Pierce Chemicals) volatile acylated derivatives were formed (*5*). When NE and DA were reacted with PFPA in the presence of ethyl acetate at 60°C for 30 minutes, four pentafluoropropionyl groups (PFP) were introduced in NE and α-MNE, while three PFP groups were introduced in DA and α-MDA (see Fig. 1). Using an LKB 9000 GC-MS equipped with the accelerating voltage alternator, we confirmed the structures of the four PFP amines by mass spectral analyses (Fig 1). For the GC we used a 12-foot (4-m) glass column (inside diameter, 2 mm) packed with OV 17 (3 percent) on Gas Chrom Q 100–120 mesh (Applied Science, College Park, Pa.), with a flash heater at 280°C, a column oven at 180°C, and helium flow at 20 ml/min. For the mass spectrometer we used a molecular separator at 240°C, an ion source at 290°C, electron energy at 80 ev, a trap current at 60 μa, and an electron multiplier of 3.7 kv.

Mass spectral analysis (Fig. 1) revealed that the catecholamine-PFP derivatives have two major fragmentation patterns: (i) cleavage of the bond between the α and β carbon atoms with retention of the positive charge on the nitrogen-containing fragment and (ii) cleavage of the bond between the α carbon and the nitrogen. The positive charge is retained on the catechol fragment and one hydrogen atom is transferred onto the neutral moiety. The specific fragments used in this analysis for each compound and their ratios are reported in Table 1. This information was relevant because, for mass fragmentography, the magnetic field of the MS was held constant at a *m/e* setting equivalent to the mass number of the most abundant fragment generated from the compound being eluted from the GC. Since the α-methyl analog derivatives have a fragmentation pattern similar to that of the amine derivatives, it seemed that they would serve as reliable internal standards. It is also necessary that the amines form PFP derivatives in amounts proportional to the initial concentration of catecholamines. Mass

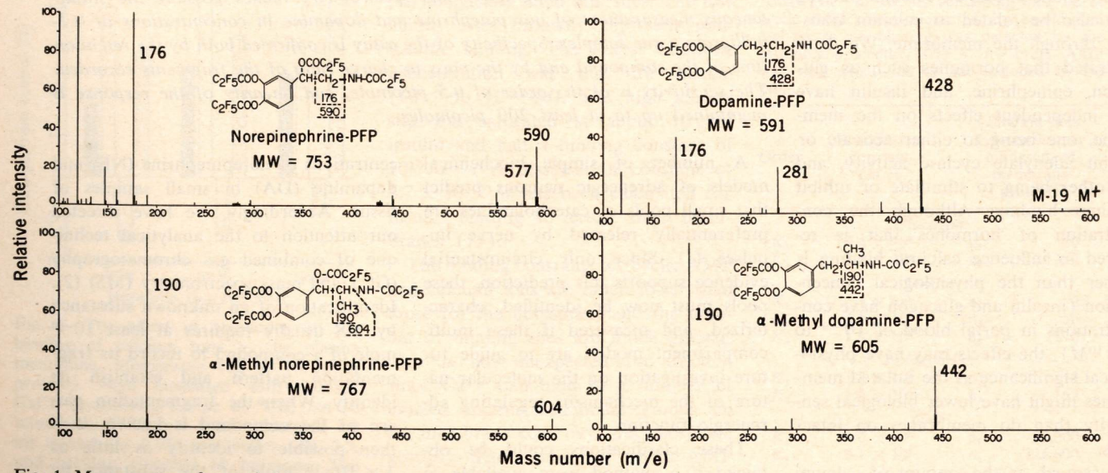

Fig. 1. Mass spectra of α-methylnorepinephrine, norepinephrine, α-methyldopamine, and dopamine pentafluoropropionyl derivatives. For mass spectrometric conditions, see text. A molecular peak (M^+) is only observed for dopamine-PFP; *MW*, molecular weight.

fragmentographic analysis showed that, when 0.5 to 200 pmole of each amine reacted with an excess of PFPA (100 μl) at 60°C in the presence of 20 μl of ethyl acetate, acylation of the catecholamines reached a steady state at 30 minutes. Using similar conditions, we have measured the amounts (5 to 50 nanomoles) of unreacted amines by a spectrofluorometric assay (*6*). In this procedure an aqueous solution of each amine was dried under nitrogen and reacted with PFPA in ethyl acetate at 60°C. At the end of 30 minutes the excess PFPA was blown off with nitrogen, and the dried acylated catecholamines were taken up into benzene. The unreacted amines, which were left in the reaction vessel, were taken up into acid and processed according to a spectrofluorometric assay (*6*). This procedure showed that, at the end of a 30-minute reaction, the amount of unreacted amines ranged from 5 to 15 percent of the original concentration. When this procedure was followed in the absence of PFPA, 95 percent of the catecholamines were recovered. These reaction characteristics applied to NE, DA, and the two internal standards. It was further determined by mass fragmentography that the amine-PFP derivatives once formed were stable for at least 24 hours if maintained in the presence of PFPA. The amine-PFP derivatives were less stable provided that the excess PFPA was removed and the residue was reconstituted in ethyl acetate for analysis. However, by recording the ion density of the most abundant fragment generated by each amine derivative, we found that the ratio of the ion density (measured as peak height) generated by the amine and its corresponding internal standard (NE-PEP with α-MNE-PFP; DA-PFP with α-MDA–PFP) remained constant for at least 10 minutes.

The PFP amine derivatives and their internal standards thus fulfill the basic requirement of having similar fragmentation patterns, react satisfactorily with pentafluoropropionic anhydride, and have a similar time constant for their stability. We tested the linearity of the reaction by holding the concentrations of the α-methyl analogs constant (20 pmole) and varying the concentration of NE and DA from 0.5 to 200 pmole. Each sample containing all four amines was processed separately and analyzed by mass fragmentography (Fig. 2A). The amine derivatives are identified by recording the ion density of a fragment at a specific *m/e* at its characteristic GC retention time (Table 1). For quantitation of the amines, the peak heights, which are proportional to the specific ion density of all four derivatives were measured. The ratio between NE-PFP (*m/e* 176) or DA-PFP (*m/e* 428) and their respective internal standard α-MNE–PFP (*m/e* 190) and α-MDA–PFP (*m/e* 442) was plotted on the ordinate with the absolute amine concentration (in picomoles) on the abscissa. In this way, a linear relation was obtained. This calibration was done in parallel with tissue assays, and the standard amine–internal standard line was used to determine the unknown amine concentration in the tissue.

Table 2. Mass fragmentographic assay of NE and DA in rat tissue. The number of analyses is given in parentheses. The results are given as the number of picomoles per sample.

Tissue	Wet weight (mg)	NE (pmole)	DA (pmole)
Superior cervical ganglion	1.4	100 ± 8.6 (7)	18 ± 2.3 (7)
Locus coeruleus	< 0.100	20 ± 1.6 (6)	3.2 ± 0.25 (6)
Striatum	27	54 ± 2 (3)	2200 ± 140* (3)
Cerebellum	250	270 ± 66† (4)	53 ± 10 (4)
Vas deferens	41	5300 ± 160‡ (5)	65 ± 8.2 (5)

Values obtained from the literature were converted to picomoles per sample to allow for direct comparison with the values in the table: * 1701 ± 89 (*9*); † 222 ± 19 (*10*); ‡ 4600 ± .41 (*11*).

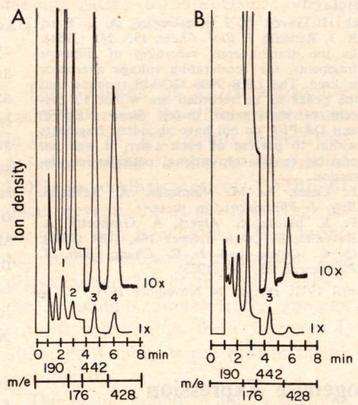

Fig. 2. (A) Mass fragmentogram of standard amine-PFP mixture. The derivatives in 10 μl of ethyl acetate were injected (2 μl) into the GC-MS, and the ion density of the most abundant fragment (*m/e*) of each compound recorded at its characteristic retention time; (1) α-MNE-PFP (20 pmole), 0 to 2.5 minutes at *m/e* 190; (2) NE-PFP (32 pmole), 2.5 to 3.6 minutes at *m/e* 176; (3) α-MDA-PFP (20 pmole), 3.6 to 5.1 minutes at *m/e* 442; and (4) DA-PFP (31 pmole), 5.1 to 7.0 minutes at *m/e* 428. (B) Mass fragmentogram obtained from analysis of 1/60 of a homogenate of a rat superior cervical ganglion. Internal standards (peaks 1 and 3) were added to the sample before processing. The peak between 1 and 3 has a retention time and fragmentation pattern which corresponds to NE-PFP, and the peak after 3 corresponds to DA-PFP.

To ascertain whether this linearity applied to tissue, we homogenized a superior cervical ganglion, a few milligrams of the corpus striatum, and a few milligrams of the vas deferens of a rat in 60 μl of 0.1*M* formic acid containing ascorbic acid (50 mmole). Samples (3 to 5 μl) of the homogenate were removed for protein analyses (*7*), and the homogenate was centrifuged ($1.2 \times 10^4 g$, 15 minutes, 4°C). Portions of the supernatants were transferred to vials containing 20 pmole each of the two internal standards (α-MNE and α-MDA); the samples were dried under nitrogen and processed with PFPA as described. A typical record for the sympathetic ganglion is shown in Fig. 2B.

The ratios between the ion densities generated by α-MNE–PFP (*m/e* 190), α-MDA–PFP (*m/e* 442), and by NE-PFP (*m/e* 176) in sympathetic ganglia and by DA-PFP (*m/e* 428) in striatum were measured and plotted on the ordinate against the tissue protein contained in each portion of the homogenate (abscissa), thus obtaining a straight line for each tissue.

The fragmentation patterns of NE-PFP and DA-PFP do not avail themselves to simultaneous multiple ion analysis with the LKB GC-MS 9000 (*8*). Mass fragmentography requires the analysis of at least two specific fragments at specific retention times. Specificity is then ascertained by comparing the ratios of the fragment intensities obtained from tissue analysis to those generated from pure standards. To satisfy this requirement, samples prepared from different tissue were first analyzed by focusing on the more abundant fragments of NE-PFP and DA-PFP, as stated above. A second analysis was then made; for NE-PFP the intensity of the fragment at *m/e* 590 was measured, and for DA-PFP the fragment at *m/e* 176 was measured (Table 1; Fig. 1). In both instances the

fragments recorded for α-MNE–PFP and α-MDA–PFP were the same: *m/e* 190 and *m/e* 428, respectively. Because of unavoidable differences between two analyses, it was necessary to use the internal standards to normalize the values for DA-PFP and NE-PFP. In this way, the ratio for two fragments analyzed for endogenous NE-PFP (*m/e* 176/590) and DA-PFP (*m/e* 428/176) compared with the ratios obtained from pure standards analyzed in the same way and with peak ratios calculated from the mass spectra (Table 1). Tissue samples were also processed without internal standards to ascertain that the fragments measured for the internal standards originated from the α-MNE and α-MDA added to the tissue sample and were not "biological background."

To demonstrate the practical significance of this method, we measured the NE and DA content in various tissues (Table 2). The data show that the concentrations of catecholamines detected with mass fragmentography compare with the reported available data. The true value of this method is that it can be applied to the study of catecholamines in very discrete brain structures weighing less than 100 μg (Table 2).

Thus the combined techniques of GC-MS can be used to quantitatively analyze 10^{-13} to 10^{-14} moles of endogenous amines. The compounds are separated by the GC and measured with the MS. The assay procedure is relatively rapid and we can process 15 to 20 samples in a day's work, including their dissection and the necessary standard curves. Considering the specificity given by the GC retention time and, more important, from the ion density recorded at a specific *m/e* setting during the elution of the various compounds from the GC, the specificity of this method surpasses and cannot be compared to any other existing quantitative method.

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Genetic Control of Lactate Dehydrogenase Expression in Mammalian Tissues

Abstract. *The amount of lactate dehydrogenase isozyme 4 in erythrocytes of mice is controlled by alleles at the* Ldr-1 *locus. The A subunits of lactate dehydrogenase from erythrocytes deficient in isozyme 4 cannot assemble in vitro with B subunits to form active isozyme. The inability to form hybrid enzyme is not due to a mutation in the structural gene for the A polypeptide. Rather, a factor that is bound to the A subunits of erythrocytes restricts free exchange with B subunits.*

The concentration of an enzyme in a mammalian cell is probably regulated at the level of synthesis or intracellular degradation (*1*). However, for those enzymes composed of more than one polypeptide chain, another level at which regulation could occur is the assembly of subunits to form the active enzyme. Rosenberg (*2*) showed that the two subunits of lactate dehydrogenase (LDH) in fish probably combine in vivo in a nonrandom fashion to form tissue-specific isozyme patterns, a result that suggests that the primary structures of the subunits are not the only determinants of the quaternary structure of the active enzyme. Fritz *et al.* (*3*) also proposed that the changes in rat heart LDH isozymes during development are regulated by events after synthesis of the polypeptide chains. If the quaternary structure of an enzyme is determined both by the primary structures of its polypeptides and by the environment in which these polypeptides assemble, then mutations that alter the environment could affect the expression of the enzyme. In this report we present evidence that the pattern of LDH isozymes in erythrocytes in mice is regulated by a factor (or factors), under genetic control, that affects the assembly of LDH subunits.

Mammalian LDH is a tetramer of two dissimilar subunits, A and B, which assemble in all possible combinations to form five isozymes. Isozymes LDH-1, LDH-2, LDH-3, LDH-4, and LDH-5 have subunit compositions of B_4, B_3A_1, B_2A_2, B_1A_3, and A_4, respectively. These isozymes differ in charge and can be separated by electrophoresis (Figs. 1 to 3) or ion-exchange chromatography (*4*).

Shows and Ruddle (*5*) described a variant of the LDH pattern in mice. Erythrocytes of most inbred strains contained only LDH-5, but erythrocytes of strains SWR/J, DE/J, LP/J, and DW/J contained both LDH-5 and LDH-4. Thus, erythrocytes of the latter strains contained both A and B subunits, but erythrocytes of all other strains contained only A subunits. The tissue-specific isozyme patterns in all other tissues were identical among the strains. The erythrocyte pattern is inherited as a single Mendelian factor and is under the control of alleles at a locus *Ldr-1*, which is on linkage group XI (*6*).

Figure 1 shows the LDH isozymes from erythrocytes of mice homozygous for alternate alleles at the *Ldr-1* locus. Isozyme LDH-4 is deficient in the homozygous *Ldr-1*^{a} strain, C57BL/6J. When the LDH isozymes in erythrocytes were separated on diethylaminoethyl cellulose (DEAE-cellulose), LDH-4 was about 1 percent of the LDH activity in the C57BL/6J strain; in contrast, this isozyme was about 4 percent of the LDH activity in the homozygous *Ldr-1*^{b} strain, SWR/J. The tissue-specific isozyme contents of kidney, liver, and heart of the two strains was identical. Thus, the defect in LDH-4 expression is restricted to the erythrocyte.

A possible explanation for the tissue-specific effect of mutation at the *Ldr-1* locus is that this locus controls

a factor (or factors) in the erythrocyte, and that the factor in the *Ldr-I*^{a} strain restricts assembly of A and B subunits to form LDH-4. We examined this possibility with the technique of molecular hybridization in vitro.

In dissociation and recombination studies (*7*), LDH-5 (A_4) from erythrocytes of SWR/J mice—the isozyme either in hemolyzates or partially purified—was tested with LDH-1 (B_4) from kidneys of either SWR/J or C57BL/6J mice. Five isozymes were formed, as predicted from random assembly of subunits (Fig. 2). Conversely, LDH-5 from C57BL/6J erythrocytes, in hemolyzates or purified 70-fold, did not combine with LDH-1 from either strain, regardless of the quantity of B subunits available for hybridization (Fig. 2, d and f). The inability of LDH-5 from C57BL/6J erythrocytes to hybridize is probably not due to a mutation in the structural gene for the A polypeptide. Isozymes LDH-1, LDH-3, and LDH-5 were partially purified from kidney, and LDH-5 was partially purified from erythrocytes; corresponding isozymes from the two strains were indistinguishable as judged by electrophoretic mobility in polyacrylamide gels, stability to heat, and stability to denaturation with urea. Isozyme LDH-5 from erythrocytes appeared identical to the same isozyme from kidney by these criteria. A mutation in the polypeptide chain would be expected to affect the A subunits of every tissue. The isozyme pattern was normal in all tissues except erythrocytes. Furthermore, when A and B subunits from other tissues of both strains were dissociated and recombined, five isozymes were formed, a result that indicates that the *Ldr-1* locus affects the A subunit of only the erythrocyte.

Isozyme LDH-5 from C57BL/6J erythrocytes inhibits the ability of LDH-5 from SWR/J erythrocytes to associate with LDH-1 (Fig. 3, a and b). The factor restricting association of subunits is purified along with LDH-5 from C57BL/6J erythrocytes through ion-exchange chromatography, $(NH_4)_2SO_4$ fractionation, and chromatography on Sephadex G-100. However, the factor can be released from LDH-5 by heat denaturation of the isozyme. The supernatant fraction after heat treatment contains no LDH activity but prevents the A subunits of SWR/J erythrocytes from hybridizing with kidney B subunits (Fig. 3c).

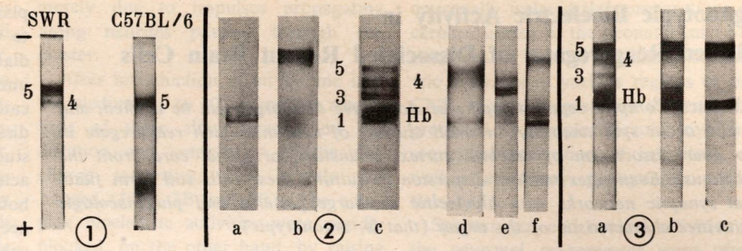

Fig. 1. Lactate dehydrogenase isozymes in erythrocytes of SWR/J and C57BL/6J mice. Hemolyzates were subjected to electrophoresis in polyacrylamide gels (*10*), and the LDH isozymes were localized as described by Vesell and Bearn (*11*). Activity was assayed as described by Markert and Faulhaber (*12*). The gel containing C57BL/6J hemolyzate was overloaded in an attempt to demonstrate LDH-4. The protein band toward the anode is hemoglobin. Fig. 2. Dissociation and recombination of LDH isozymes. Kidney LDH-1 from both strains was separated from the other isozymes by DEAE-cellulose chromatography of a 105,000*g* supernatant fraction. Isozyme LDH-5 from erythrocytes of both strains was partially purified by DEAE-cellulose chromatography, $(NH_4)_2SO_4$ fractionation, and Sephadex G-100 chromatography. Samples are (a) LDH-1 from kidney of strain SWR/J; (b) LDH-5 from erythrocytes of strain SWR/J; (c) 80 units of SWR/J LDH-1 hybridized with 80 units of SWR/J erythrocyte LDH-5; (d) 60 units of SWR/J LDH-1 hybridized with 60 units of C57BL/6J LDH-5; (e) 160 units of C57BL/6J kidney LDH-1 hybridized with 80 units of SWR/J erythrocyte LDH-5; and (f) 160 units of C57BL/6J kidney LDH-1 hybridized with 80 units of C57BL/6J erythrocyte LDH-5. Each hybridization mixture contained 1*M* NaCl and was either frozen once in Dry Ice or twice at −15°C (*Hb*, hemoglobin). Fig. 3. The presence of a factor restricting subunit association in C57BL/6J erythrocytes. Hybridization mixtures a and b contained 80 units of SWR/J kidney LDH-1. In addition, mixture a contained 80 units of SWR/J erythrocyte LDH-5. Mixture b contained 40 units each of SWR/J and C57BL/6J erythrocyte LDH-5. Mixture c contained 60 units of both erythrocyte LDH-5 and kidney LDH-1 from the SWR/J strain plus the supernatant (0.4 ml) obtained after heating a preparation of C57BL/6J erythrocyte LDH-5 for 10 minutes at 100°C (*Hb*, hemoglobin).

The subunits of LDH apparently exchange among the different isozymes in situ (*3, 8*). Our results suggest that a factor bound to the A subunits of LDH in erythrocytes of C57BL/6J mice prevents the A subunits from associating with B subunits. Thus, during the normal course of association and disassociation of erythrocyte LDH-5, the A subunits cannot freely combine with B subunits to form isozyme 4, although B subunits are present in the erythrocyte.

The factor bound to the A subunits of C57BL/6J erythrocytes has not been identified, but it has many of the properties of the derivative of reduced nicotinamide adenine dinucleotide which was described by Gelderman and Peacock (*9*). This derivative also binds to LDH-5; it is difficult to remove by ion-exchange chromatography, $(NH_4)_2SO_4$, or dialysis; and it is stable to heat. Whatever the nature of the factor restricting subunit assembly, the amounts of the individual LDH isozymes in the erythrocyte do not result from a random tetramerization of the two subunits. Rather, the quaternary structure of LDH is determined at least in part by tissue-specific mechanisms. These mechanisms are under genetic control but are not related to the structural genes for the A and B polypeptides or directly to the rates of subunit synthesis and degradation.

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Organotypic Bioelectric Activity in Cultured Reaggregates of Dissociated Rodent Brain Cells

Abstract. *Complex repetitive-spike or slow-wave discharges can be evoked, and can also occur spontaneously, in small clusters of neurons which reaggregate in vitro after dissociation of cerebral cortex, brainstem, or spinal cord from the fetal mouse. Even after random dispersion in culture, these cells still form functional synaptic networks with bioelectric discharge patterns and pharmacologic sensitivities characteristic of the organ (that is, organotypic).*

Explants (~ 1 mm^3) of tissues from the central nervous system (CNS) of mammalian fetuses develop the capacity to generate synaptically mediated repetitive-spike or slow-wave discharges, characteristic of the organized CNS (organotypic), during maturation in culture (*1*). This occurs even when the tissue is isolated at stages prior to the formation of synapses in situ. Microelectrode recordings have also now been made on small clusters of neurons after reaggregation in vitro of cells, dissociated by trypsin, that were obtained from the cerebral neocortex of 18-day fetal mice or from spinal cord or brainstem of 13- to 14-day fetal mice ("presynaptic" stages). In studies of dissociated cells from the spinal cord and muscle of chick embryo in culture (*2*) intracellular postsynaptic potentials were obtained "which, in some cells, occurred in definite patterns and at regular intervals." Our data extend these experiments to cells of the fetal mammalian spinal cord and brain, and they demonstrate that complex organotypic patterns of bioelectric discharges can be generated by small reaggregated clusters developing from randomly dispersed neurons in culture.

The CNS tissues were dissociated with trypsin and cultured as described for chick neural tissues (*2, 3*), except that the cover glasses were coated with collagen and sealed into Maximow depression-slide chambers (*4*). The tissues were exposed to trypsin (0.25 percent) and repeated pipetting, and then suspensions of cells (~ 10^6 cells per milliliter of culture medium) were explanted onto collagen films, using 0.05 to 0.1 ml per cover glass (22 mm in diameter). Microscopic observation immediately after explantation indicated that the cells had been completely dissociated prior to culture. Cytologic studies indicated development of characteristic neurons and glial cells (*5*), both within the clusters and in the connecting neuritic bridges (Fig. 1). Development of abundant axon-dendrite and axon-soma synapses has been demonstrated by electron microscopy of these reaggregated neurons, as in intact explants of fetal cerebrum (*5, 6*), and in cultured reaggregates of dissociated cells from the spinal cord, retina, and spinal ganglion of the chick (*3*). Well-organized histologic patterns have also been observed in larger reaggregates developing in rotatory suspension cultures of dispersed cells from the brain of fetal mice (*7*).

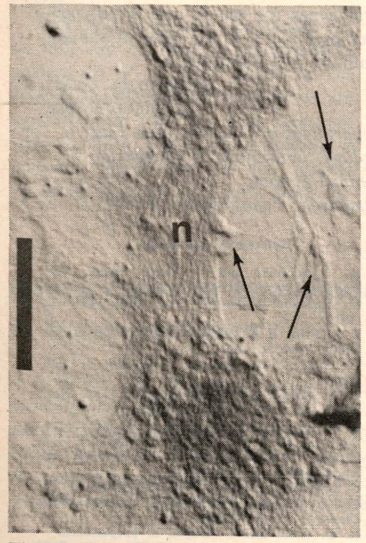
Electrophysiologic studies on dissociated neurons from the CNS were carried out with similar techniques as with intact explants of the CNS (*1, 8*). Extracellular recordings were made with silver–silver chloride electrodes using pipettes (1- to 5-μm tips) filled with saline; the amplifier passband ranged from 0.2 hz to 10 khz. Electric stimuli (0.1 to 0.5 msec) were applied through pairs of similar pipettes with 10-μm tips. The cover glass was transferred from the Maximow slide to a larger, closed, chamber that was mounted on an inverted microscope. Electrodes, attached to small micromanipulators incorporated into this sealed chamber, were brought up to individual cells (under microscopic observation) (Fig. 3) by the use of external magnetic controls (*9, 10*). Recordings were made while the cells were in a bath containing about 0.5 ml of physiological salt solution (Simms balanced salt solution equilibrated with 3 percent CO_2 to maintain *p*H around 7.2), at 34° to 35°C.

After the cells were in culture 2 to 4 weeks, we recorded complex, evoked and spontaneous, repetitive-spike discharges from dozens of discrete neuronal clusters that were attached to the cover glass over an area of about 1 cm^2, and that were connected to one another by neuritic bridges (Figs. 2A and 4A). In the larger clusters with dozens of neurons, characteristic long-lasting potentials were often observed in association with the spike barrages. The complex bioelectric potentials recorded from each cluster were clearly generated within the cell cluster and were not merely due to impulses propagating along neurites passing through the cluster.

After introduction of strychnine into the medium (1 to 10 μg/ml) the amplitude of these slow waves, and the duration and complexity of the discharge sequences, were greatly enhanced (Figs. 2B and 4B). The complex bioelectric activities were rapidly blocked, on the other hand, by raising the Mg^{2+} concentration of the medium from 1 to 5 m*M* (Fig. 4, C and D), although spike potentials with short latent periods could still be evoked. The sensitivity of these reaggregated CNS neurons to pharmacologic agents is similar to that observed in larger intact CNS explants (*1, 11*); the data suggest that the complex discharges generated in both types of CNS cultures are based upon synaptic network activity as occurs in situ (*12*). In some of the reaggregates, oscillatory (~ 10 to 15 per second) afterdischarge patterns occurred spontaneously, as well as in response to stimuli (Fig. 4B). These stereotyped, yet complex, rhythmic discharges have, until now, been observed only in well-organized, undissociated explants from the CNS (*1, 13*), and resemble repetitive discharge patterns of neuronally isolated slab preparations of cerebral cortex of the neonatal cat (*14*). Analyses of similar rhythmic bioelectric activities in various regions of the CNS, in situ, suggest that they may be produced by complex circuits involving sequential generation of inhibitory, as well as excitatory, postsynaptic potentials (*15*).

Spontaneous and evoked activities in the neuronal reaggregates were often synchronized, even between clusters that were 2 to 3 mm apart (Figs. 2 and 4). The marked variation in latency periods of the discharges between clusters reflect slow propagation of impulses in immature neurites and complex polysynaptic delays. After the addition of strychnine, however, synchronization was greatly enhanced and even some of the small clusters containing only a few neuron perikaryons then showed patterned, long-lasting, repetitive-spike bursts concomitant with more complex discharges in larger clusters.

Since these dissociated neurons from the CNS can now be studied with cytologic and electrophysiologic techniques during the entire period of regeneration and aggregation in culture (*10*), this method should facilitate analysis of the



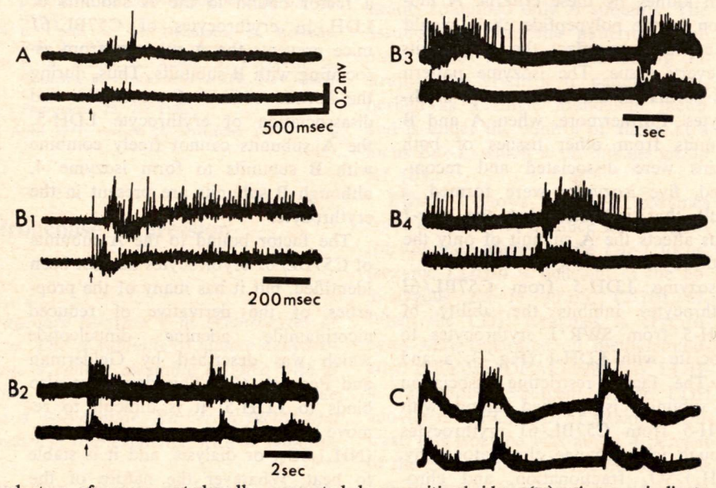
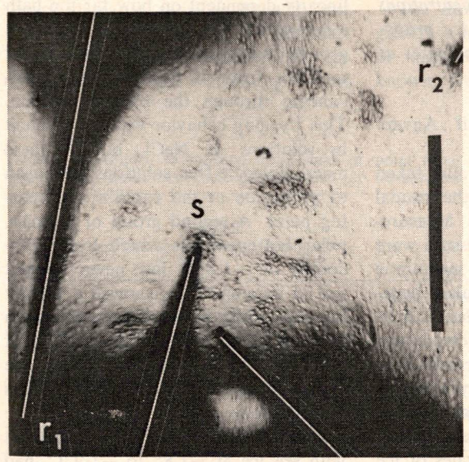


Fig. 1 (left). Photomicrograph showing two clusters of reaggregated cells connected by neuritic bridge (*n*). Arrows indicate neuron cell bodies near clusters in looser array. Scale, 100 μm. Fig. 2 (right). Complex bioelectric discharges in cultured reaggregates of brainstem and spinal cord tissues from fetal mouse, 2 weeks after dissociation. (A) Simultaneous microelectrode recordings of repetitive-spike barrages and long-lasting, negative, slow-wave responses in two similar clusters of reaggregated neurons (3 mm apart), elicited by a single stimulus applied to the intervening tissue. (B) After addition of strychnine to medium (10 μg/ml), evoked discharges were enhanced in amplitude, duration, and complexity (B_1 and B_2), and similar potentials also occur spontaneously, and synchronously, between these distant regions of the neuronal network (B_3 and B_4). (C) Records of similar complex, spontaneous discharges from two reaggregated clusters (~ 3 mm apart) in another culture of dissociated brainstem and cord tissues, under influence of strychnine. (Time and amplitude calibrations apply to all succeeding records, until otherwise noted.) Upward deflection indicates negativity at focal recording electrode; onset of stimulus is indicated by pulse (or arrow) below second sweep.



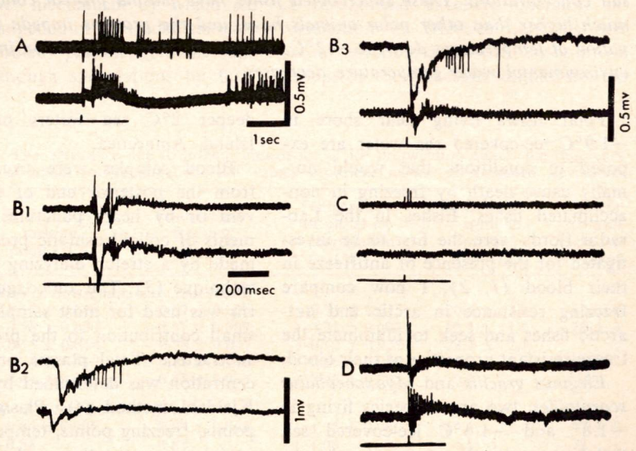


Fig. 3 (left). Photomicrograph obtained during electrophysiologic recording from this culture of aggregates of cells from the cerebral cortex of fetal mouse, 2 weeks after dissociation. (White line through axis of each micropipette; cluster r_1 not visible at this low magnification due to optical distortion produced by pipettes dipping into bath fluid). Scale, 1 mm. Fig. 4 (right). Organotypic spike barrages and oscillatory afterdischarges in culture seen in Fig. 3. (A) Long-lasting, intermittent bursts of repetitive spikes in two clusters of reaggregated neurons (r_1 and r_2) (2 mm apart) evoked by single stimulus applied to intervening clusters. (B_1) After addition of strychnine to the medium (10 μg/ml), slow-wave components are enhanced in amplitude, and rhythmic positive potentials (~ 15 per second) appear during long-lasting negativity. (B_2) Similar repetitive sequences also occur spontaneously, and synchronously, between the two clusters. There is a sequential increase in amplitude of spikes during spontaneous and evoked discharges (B_2 and B_3). (C) After increasing the concentration of Mg^{2+} from 1 m*M* to 5 m*M*, all complex discharges were blocked, and only brief spikes with short latent periods could be evoked. (D) Restoration of complex discharges after the concentration of Mg^{2+} was returned to 1 m*M*.

role of each cell of these synaptic networks in generating organotypic bioelectric discharges as a model of CNS activity.

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Freezing Resistance in Polar Fishes

Abstract. *Arctic and antarctic fishes, living in contact with sea ice at − 1.9°C, have plasma equilibrium freezing points near − 1.2°C which are dependent on salt concentrations. These supercooled fishes have plasma protein concentrations much higher than other polar animals have, and the proteins impede ice propagation at temperatures down to − 2°C. Plasma protein concentration increases as environmental water temperature decreases.*

Polar fishes living near shore in −1.9°C ice-covered sea water are exposed to conditions that would normally cause death by freezing in nonacclimated fishes. Fishes in the Labrador fjords were the first to be investigated for the presence of antifreeze in their blood (*1, 2*). I now compare freezing resistance in arctic and antarctic fishes and seek to illuminate the freeze-resistant properties of their blood.

Eleginus gracilis and *Myoxocephalus scorpioides*, two arctic species living in −1.8° and −1.4°C ice-covered sea water, respectively, were caught by a hook and line at a depth of 2 m near Nunivak Island, Alaska. Two antarctic shallow-water fishes (*Notothenia coriiceps* and *Notothenia gibberifrons*) were caught in 2°C sea water near shore at Anvers Island, Antarctica. Two antarctic hemoglobin-free icefishes (*Chaenocephalus aceratus* and *Pseudochaenichthys georgianus*) were caught in deeper 2°C sea waters off Anvers Island, Antarctica.

Blood samples were usually taken from the posterior end of the caudal vein or by heart puncture. Measurements of colloid osmotic pressure were made by a stretch dialyzing membrane technique (*3*). The anticoagulant heparin was used for most samples, and its small contribution to the pressure was subtracted. Total plasma protein concentration was determined by a micro-Kjeldahl method (*4*). Plasma melting points, freezing points, temperatures of initial ice propagation, and rates of ice propagation were determined by a field technique modified from Scholander *et al.* (*1*). Modifications included a viewing port on the side of a copper box insulated with Styrofoam. Adjustment of the bath temperature was accomplished using heating wires connected to a variable transformer. With zero heat input, bath temperature remained constant at −4°C. Ice crystals were observed with a 20-power microscope. A 5-mm³ plasma sample was frozen with "Spra-Freeze" (Laboratory Supplies Co.); then melting and freezing points were determined by observing the last small upward-floating ice crystal.

The melting point, determined to within 0.01°C, was the temperature at which the last small upward-floating crystal began to blur. The freezing point, measured with equal precision, was the temperature at which the edges of this last crystal began to sharpen. In NaCl solutions the melting and freezing points show a disparity of approximately 0.01°C when this apparatus is used (see Table 1). On the other hand, this disparity can be several times greater in a concentrated protein solution. Moreover, one must be careful to distinguish the equilibrium freezing point from the temperature of initial ice propagation in plasma. The former is 0.01° to 0.09°C below the equilibrium melting point, whereas the latter can be 1.00°C below the equilibrium melting point (Table 1).

Studies of ice growth in the plasmas of polar animals necessitated a trichotomy of ice propagative characteristics (Table 1). In the control group of animals, birds and mammals, ice propagation in plasma began at temperatures just below the equilibrium freezing point and the propagation rate was linearly dependent on how far the bath temperature was below this point. Ice growth occurred by bulk freezing and took the form of feathery plumes advancing through the plasma solution. This freezing behavior was also evident in solutions of NaCl, but in these macromolecule-free solutions ice began to propagate at the equilibrium freezing point. A second group of animals, polar bottom fishes which live supercooled at −1.8°C but never contact sea ice or anchor ice, showed a slightly larger disparity between the equilibrium freezing point and the temperature of initial ice propagation. Growing ice crystals took a dendritic form in this second group also. A third group, the nearshore fishes that live in contact with sea ice at −1.8° to −1.9°C, had strikingly different ice propagative behavior in their plasmas. When the bath temperature was dropped slightly below the plasma equilibrium freezing point in these fishes (noted by the sharpened ice crystal edge), a small amount of crystal growth occurred but then suddenly stopped. Upon further lowering of bath temperature (from 0.8° to 1.2°C below the freezing point), a temperature was reached at which sharp, monoclinic spears shot through the plasma. This was the temperature of initial ice propagation.

The rates of ice propagation in 5-mm³ plasma samples of the three groups of polar animals illustrate further the freezing resistance present in the shallow-water fishes (Fig. 1). Rates were measured in the apparatus previously described by timing the linear progress of ice needles along a 10-mm microscope reticle (100 divisions) while maintaining constant bath temperature. The polar birds and mammals exhibited a gradual increase in ice propagation rate just below their equilibrium freezing points. These plasmas displayed freezing behavior most like simple NaCl solutions in which feathered-type ice propagation began at the equilibrium freezing point. The second group, the antarctic deep-bottom fishes (*Chaenocephalus aceratus*), showed a slightly greater increase in rate with bath temperature with ice growth occurring 0.3°C below the freezing point. The third group, the antarctic shallow-water fishes (*Notothenia coriiceps*) living in contact with sea ice, exhibited a 0.9°C disparity between their equilibrium freezing point and the temperature of initial ice propagation. Furthermore, below this latter temperature, propagation rates of monoclinic ice spears increased capriciously with just slight lowering of bath temperature. Thus, these shallow-water fishes are much more resistant to freezing due to their inhibition of ice propagation between −1.18° and −2.09°C, an inhibition that is absent in other polar animals.

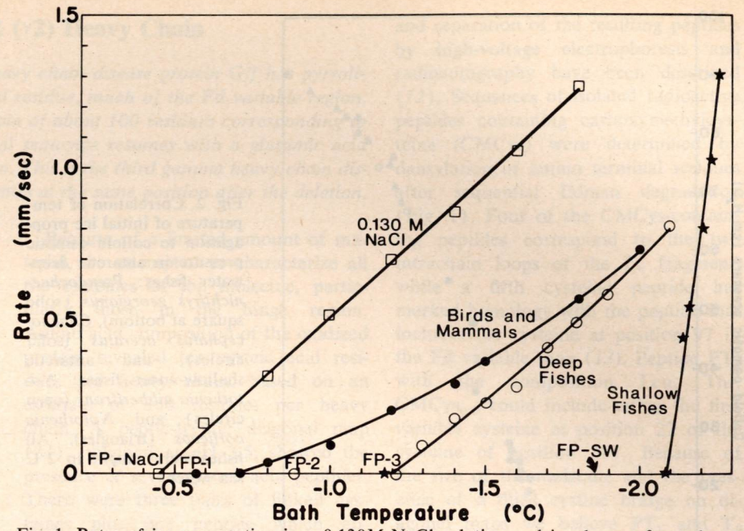

Fig. 1. Rates of ice propagation in a 0.130*M* NaCl solution and in plasmas from three groups of polar animals at various bath temperatures. The NaCl (open squares) has a freezing point (indicated by FP-NaCl) equal to its temperature of initial ice propagation (−0.45°C). The control animals (group 1), birds and mammals (solid circles), maintain a constant body temperature above ambient and exhibit freezing behavior most like that of the NaCl solution. The deep-water antarctic fishes (group 2, open circles) live supercooled but without contact with sea ice. The shallow-water antarctic fishes (group 3, stars), live supercooled in contact with sea ice. Freezing points for plasmas from groups 1, 2, and 3 are indicated by FP-1, FP-2, and FP-3. The freezing point for sea water is indicated by FP-SW.

The exact mechanism by which ice growth is impeded in ice-seeded samples of supercooled plasma remains unknown, although speculations by Umminger, Smith, DeVries, and others suggest that hydroxyl-rich compounds inhibit growing surfaces of ice crystals in the serums of supercooled fishes (*5–7*). A recent and excellent chemical investigation by DeVries indicates that serum glycoproteins with *cis*-hydroxyl groups on the galactose residues are the

Table 1. Resistance to freezing in plasmas of polar fishes. The resistance due to protein impedance of ice propagation equals the difference between the equilibrium freezing point and the temperature of initial ice propagation. All values represent means ± standard deviations.

Animal (species and number of samples)	Equilibrium melting point (°C)	Equilibrium freezing point (°C)	Temperature of initial ice propagation (°C)	Colloid osmotic pressure (cm-H_2O)	Protein concentration (g/liter)
Group 1 (controls: birds, mammals, and NaCl)					
Adélie penguin (*Pygoscelis adeliae*, 3)	−0.55 ± 0.010	−0.57 ± 0.006	−0.75 ± 0.025	20.6 ± 2.9	40 ± 6
Giant petrel (*Macronectes giganteus*, 2)	−0.56 ± 0.000	−0.57 ± 0.007	−0.71 ± 0.007	10.0 ± 1.4	28 ± 3
Spotted seal (*Phoca vitulina*, 2)	−0.55 ± 0.014	−0.58 ± 0.007	−0.62 ± 0.021	28.5 ± 2.1	
Man (*Homo sapiens*, 3)	−0.54 ± 0.010	−0.55 ± 0.006	−0.66 ± 0.006	35.7 ± 2.6	71 ± 7
0.130*M* NaCl (4)	−0.44 ± 0.005	−0.45 ± 0.003	−0.45 ± 0.005	0.0	0
Group 2 (deep-bottom fishes)					
Icefish I (*Chaenocephalus aceratus*, 11)	−0.84 ± 0.006	−0.89 ± 0.008	−1.36 ± 0.086	29.4 ± 12	60 ± 9
Icefish II (*Pseudochaenichthys georgianus*, 1)	−0.84	−0.85	−1.06	4.1	28
Group 3 (shallow-water fishes)					
Antarctic notothenid I (*Notothenia coriiceps*, 11)					
1) Caught in 2°C sea water	−0.87 ± 0.014	−0.92 ± 0.022	−1.84 ± 0.125	79.9 ± 6.8	68 ± 4
2) Acclimated to −1.8°C for 23 days	−1.10 ± 0.020	−1.18 ± 0.019	−2.09 ± 0.057	102 ± 5.7	79 ± 3
Antarctic notothenid II (*Notothenia gibberifrons*, 2)					
1) Caught in 2°C sea water	−0.88 ± 0.000	−0.91 ± 0.007	−1.73 ± 0.064	70.8 ± 4.9	61 ± 5
2) Acclimated to −1.8°C for 20 days	−1.14 ± 0.007	−1.23 ± 0.007	−2.14 ± 0.024	98.7 ± 2.3	76 ± 2
Arctic cod (*Eleginus gracilis*, 14)					
1) Acclimated to 5°C for 4 days	−1.12 ± 0.016	−1.21 ± 0.010	−1.87 ± 0.052	175 ± 9.3	
2) Caught in −1.8°C sea water	−1.18 ± 0.013	−1.25 ± 0.019	−2.16 ± 0.043	214 ± 12	
Arctic sculpin* (*Myoxocephalus scorpioides*, 3)	−1.11 ± 0.006	−1.16 ± 0.010	−2.03 ± 0.010	128 ± 2.5	

* Caught in −1.4°C sea water.

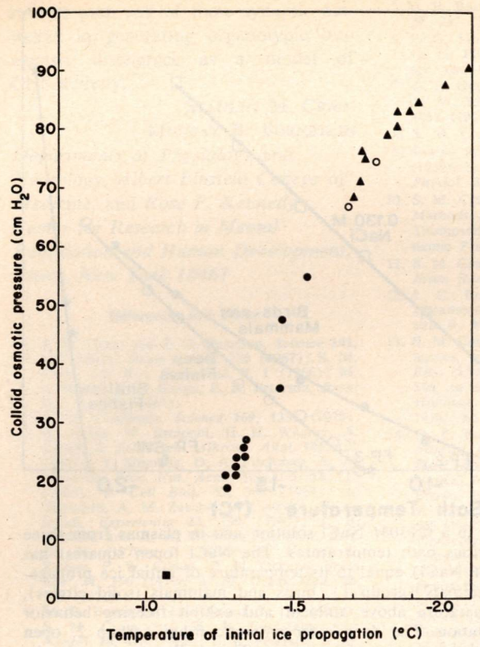

Fig. 2. Correlation of temperature of initial ice propagation to colloid osmotic pressure in antarctic deep-water fishes: *Pseudochaenichthys georgianus* (solid square at bottom), *Chaenocephalus aceratus* (solid circles), and antarctic shallow-water fishes: *Notothenia gibberifrons* (open circles) and *Notothenia corliceps* (triangles). All fishes were caught in 2°C sea water.

active agents which inhibit ice crystal growth in antarctic fishes (*6*).

Equilibrium freezing measurements (actually melting points) have demonstrated that arctic and antarctic fishes living in contact with sea ice are supercooled (*2*, *5*, *8*). The earlier freezing points determined by DeVries and collaborators (*7*, *9*) using a rate-measuring device are probably measurements of the temperature of initial ice propagation and not true equilibrium freezing point values. Consequently, although such measurements assist in identifying the antifreeze components of serum, such an apparatus fails to elucidate the actual freezing behavior. In his more recent study DeVries equates freezing point with temperature of ice crystal growth (*6*). This temperature, however, probably corresponds to the temperature of initial ice propagation as listed in this report (Table 1). The true equilibrium freezing point, identified by a sharpening ice crystal edge, is less than 0.1°C below the equilibrium melting point and considerably above the temperature of initial ice propagation (that is, the temperature of ice crystal growth).

The antifreeze components which impede ice growth at temperatures above −2°C in the antarctic notothenioids are in the protein fraction of the plasma. In order to separate the microsolute fraction from the macromolecular phase, three plasma samples from −1.8°C acclimated (23 days) *Notothenia corriceps* were ultrafiltrated in a modified centrifuge tube with a dialysis membrane as described by Scholander and Maggert (*8*). Care was taken to maintain original concentrations in each fraction. The colloid-free microsolute fraction had a slightly higher freezing point (−1.09°C) than the unaltered plasma (−1.18°C) but this microsolute fraction exhibited none of the antifreeze properties that prevent ice propagation between the freezing point and the temperature of initial ice propagation. The macromolecular fraction had a freezing point of −1.10°C and contained all the ice-inhibiting components that afford these fishes the additional 0.9°C protection below their freezing point. Similar experiments on *Notothenia gibberifrons* gave the same results. These findings verify those made earlier by Scholander and Maggert on arctic fishes (*8*) and support the thorough chemical analyses conducted by DeVries (*6*).

When the antarctic fishes caught in 2°C sea water were examined, a good correlation was found between the temperature of initial ice propagation and the colloid osmotic pressure (Fig. 2). Figure 2 also indicates the spread of plasma protein concentrations (reflected in the colloid osmotic pressure data) even within one species.

Acclimation studies suggest that there is a seasonal change in concentration of these colloidal particles, although the variation seems more pronounced in the arctic than the antarctic shallow-water fishes (Table 1). Acclimation periods are given in Table 1. The antarctic nototheniids, which experience a temperature drop of 4°C from summer to winter, exhibited a significant increase in protein concentration and associated decrease in temperature of initial ice propagation. Similar results, but greater in amplitude, were found in the arctic cod. Perhaps this is a result of their exposure to a greater drop in summer to winter temperature (usually about 12°C near Nunivak Island, Alaska). Considering the 11.3 cm-H_2O colloid osmotic pressure of a temperate-water cod (*10*), the 214 cm-H_2O mean value for the arctic cod acclimated to −1.8°C is astonishing. Certainly this high colloidal concentration protects these supercooled fishes from freeze damage. It is also interesting to note that even the freshwater arctic char (*Salvelinus alpinus*) when acclimated to 3°C from 2°C in a period of 2 weeks, displayed a decrease in mean colloid osmotic pressure from 92.5 ± 13 cm-H_2O to 26.6 ± 2.3 cm-H_2O (*11*).

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Molecular Defect in a Gamma-2 (γ2) Heavy Chain

Abstract. *The first gamma-2 (γ2) heavy chain disease protein Gif has pyrrolidinecarboxylic acid as its amino terminal residue, much of the Fd variable region, and an internal deletion of the heavy chain of about 100 residues corresponding to most of the Fd constant region. Normal sequence resumes with a glutamic acid residue at position 216 in the hinge region. This is the third gamma heavy chain disease protein where normal sequence resumes at the same position after the deletion.*

Gamma heavy chain disease (γHCD) (*1*) is characterized by the production of an aberrant protein which consists of the Fc fragment and part of the Fd fragment of immunoglobulin heavy chains (*2*). Investigations of three γHCD proteins have shown that the structural defect is an internal deletion. In protein Zuc (*3*), a γ3 protein, there is a gap of almost the entire Fd fragment starting at residue 18. The Glu (*4*) at residue 19 of Zuc corresponds to position 216 (*5*) in the normal sequence found in γ3 heavy chains, and from this point to the COOH-terminal end of the molecule it is apparently normal. Cra (*6*), a γ1 HCD protein, has a heterogeneous NH_2-terminal region. After these 11 residues normal sequence is resumed at the same residue as in Zuc. In another HCD protein, Hi (*7*), there is also an internal deletion, but its size and exact location have not been identified. Studies of these proteins may yield valuable clues about the genetic control of immunoglobulin heavy chains.

Protein Gif was isolated from the serum by starch-block electrophoresis and repeated filtration on Sephadex G-200. It was typed as a γ2 protein immunologically and chemically (*8*). Molecular weights were determined by acrylamide-gel electrophoresis in sodium dodecyl sulfate (*9*). The native protein exists as a dimer with a molecular weight of 80,000; the monomer formed by reduction has a molecular weight of 40,000.

Amino terminal analysis with the dansyl (diaminonaphthylesulfonyl) chloride method was negative, indicating a blocked NH_2-terminal. A Pronase digest of Gif was passed through a Dowex-50 column and then subjected to high-voltage electrophoresis at *p*H 6.5. A ninhydrin-negative, chloride-positive spot was identified as a dipeptide, Glu-Val. Tryptic peptide patterns of Gif contained 10 to 12 peptides in addition to those present in the Fc fragment (*10*). Since these findings suggested that Gif is an incomplete heavy chain, an attempt was made to identify the site and magnitude of the abnormality.

Because of a limited amount of material, we attempted to characterize all the cysteines of the molecule, particularly those in the hinge region. Amino acid composition of the oxidized protein revealed ten cysteic acid residues per heavy chain, based on an estimate of 360 residues per heavy chain. A peptic-tryptic diagonal map (*11*), obtained at *p*H 3.5, showed the presence of seven cysteic acid peptides. There were three pairs of linked cysteines plus one peptide which appeared unlinked. The three cystine bridges have been identified (see below) as the intrachain loop of the Fd variable region and the two intrachain loops of the Fc region (Fig. 1). The hinge peptide which contains four cysteines appears unlinked, since it is bridged to the identical peptide on the other heavy chain. We were unable to label any cysteines when the unreduced protein was alkylated in tris-guanidine, indicating the absence of any free SH groups.

Techniques for cleavage of the peptide chain by pepsin and trypsin and separation of the resulting peptides by high-voltage electrophoresis and radioautography have been described (*12*). Sequences of isolated radioactive peptides containing carboxymethylcysteine (CMCys) were determined by dansylation of amino terminal residues after sequential Edman degradation (Fig. 1). Four of the CMCys-containing peptides correspond to the two intrachain loops of the Fc fragment, while a fifth cysteine peptide has marked homology with the peptide that includes the cysteine at position 97 in the Fd variable loop (*13*). Peptide PT_1 with the composition Leu, Thr, $CMCys_{0.5}$ could include either the first variable cysteine at position 22 or the cysteine of position 367. Because of the size of the molecule and the presence of a third cystine bridge on diagonal maps we believe PT_1 and T_2 are linked and represent the intrachain disulfide loop of the Fd variable region. We were unable to identify the cysteine-containing peptides from the Fd constant region including the constant loop and the peptide joining the heavy to the light chain (Fig. 2B). This places the beginning of the deletion somewhere after residue 100, and probably at the beginning of the constant region of the Fd fragment. Since the sequence around the hinge region of a γ2 myeloma protein (Sa) is known (*14*), we attempted to characterize this region of the molecule in the hope of characterizing the

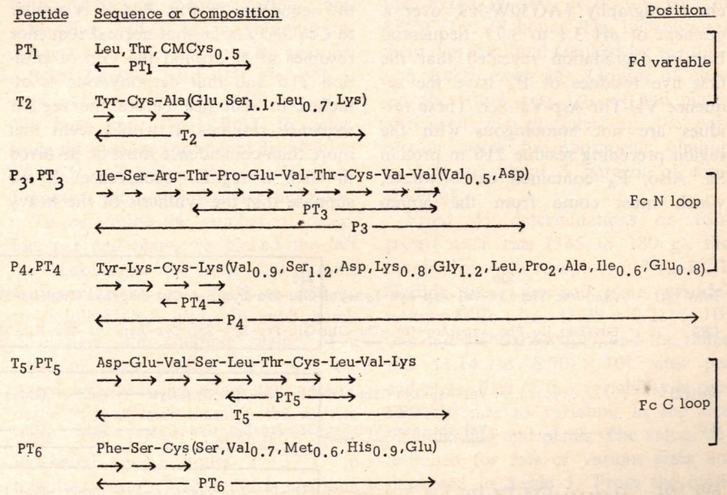

Fig. 1. Carboxymethylcysteine peptides isolated from peptic (P), tryptic (T), and peptic-tryptic (PT) digests of the fully reduced and alkylated γ2 HCD, Gif. Three intrachain disulfide bridges of the molecule are present. No CMCys peptides corresponding to the Fd constant region were identified. The heavy-light peptide is absent, and the peptide containing the interchain bridges (linking the heavy chains) is shown in Fig. 2.

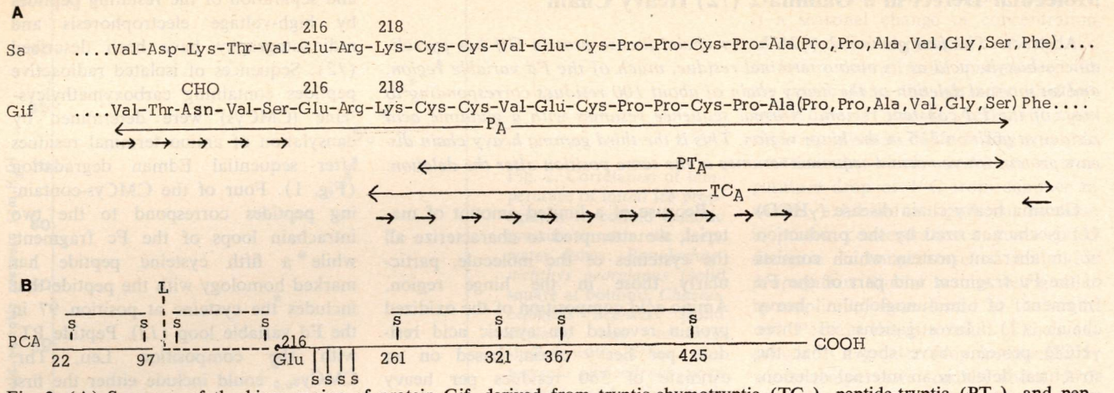

Fig. 2. (A) Sequence of the hinge region of protein Gif, derived from tryptic-chymotryptic (TC_A), peptide-tryptic (PT_A), and peptic (P_A) digests of the molecule. From the Glu at position 216 the sequence of Gif is identical with another $\gamma 2$ protein, Sa. The first five residues of P_A are not homologous with protein Sa, indicating that the normal sequence begins at position 216. Small arrows indicate residues sequenced in peptides P_A and TC_A. (B) Schematic representation of a $\gamma 2$ heavy chain monomer. The solid lines represent Gif and the dotted area is the deleted segment corresponding to the Fd constant region.

end of the deletion. A partial sequence of a peptide isolated from tryptic-chymotryptic and peptic-tryptic digests of the reduced molecule showed that the region containing the heavy chain bridges from 218 to 235 was identical to that found in Sa (*14*) (Fig. 2A). A related peptide (P_A), which contains several additional residues at the NH_2-terminal side, was then obtained (in low yield) from a peptic digest of the unreduced protein (*15*) by a series of steps that included high-voltage electrophoresis, descending chromatography with a butanol, acetic acid, water, pyridine system, and ion exchange chromatography (AG50W-X8, over a gradient of *p*H 3.1 to 3.7). Sequential Edman degradation revealed that the first five residues of P_A have the sequence Val-Thr-Asp-Val-Ser. These residues are not homologous with the region preceding residue 216 in protein Sa. Also, P_A contained carbohydrate, which must come from the amino terminus of the peptide since PT_A lacked carbohydrate (Fig. 2A). The composition of the remainder of this peptide from the Glu at position 216 to position 234 is identical with protein Sa. Not enough material was available to determine the sequence of Glu and Arg at residues 216 and 217. However, the location of the tryptic cleavage suggests that the sequence is as shown in Fig. 2A. A schematic representation of the molecule is given in Fig. 2B.

Gif differs from Zuc and Cra in the size of the deletion, but it resembles Hi in having a deletion of about 100 residues per heavy chain. As is shown by the sequences in Fig. 3, Gif is similar to Cra and Zuc in that normal sequence resumes at or around the Glu of position 216 and that carbohydrate is attached to Asn just before the regular sequence resumes. It would seem that more than coincidence must be involved in such a regular occurrence. If we suppose that the synthesis of the heavy chain is under the control of either a single or a series of closely linked genes, and that these arose by gene duplication from a smaller ancestral gene, then the sequence around residue 216 might be expected to be homologous with the NH_2-terminal of the heavy chain or the Fd constant region. However, this region which is known as the "hinge region" and contains the disulfide bridges linking the heavy chains is not homologous with any other region of the heavy or light chain and has been noted to contain the greatest subclass variability in IgG (*16*) and IgA (*17*). This lack of homology raises the possibility that it represents the product of a satellite DNA which has been inserted during the duplication of a primitive immunoglobulin gene. An alternative explanation for the observed lack of homology and great variability of this region is that, while it represents the results of gene duplication, it is unique because of still unknown functional requirements that have permitted this degree of variability during evolution.

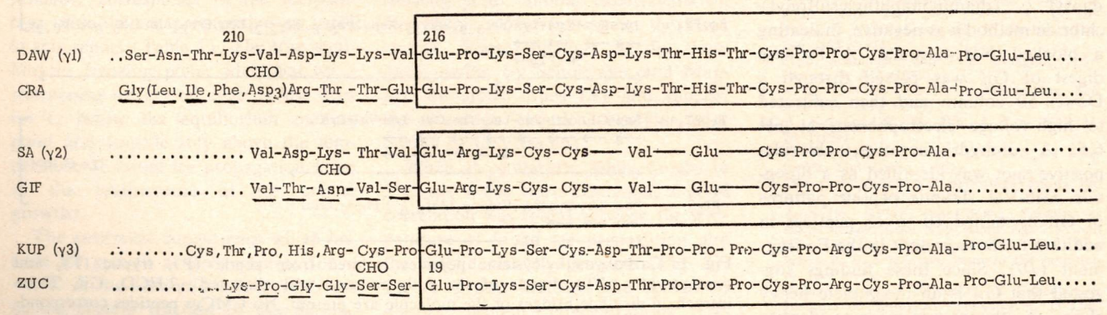

Fig. 3. The sequence from the hinge region of three HCD proteins as compared to the known sequence of proteins of the same subclass (*3, 13, 14*). All three HCD proteins begin regular sequence at position 216, and carbohydrate is attached to the molecule just before this site. Underscoring indicates the nonhomologous regions preceding the normal sequence.

Since the four known subclasses of γ chains are under the control of a series of closely linked genes (*18*), it seems particularly striking that, as is shown in Fig. 3, γHCD proteins belonging to three of these subclasses have normal sequences after the same position. Thus it seems possible that Glu at residue 216 near the hinge region could represent the beginning of another gene. The data on two other immunoglobulins with large deletions do not provide further support for this possibility. The deletion in protein Hi has not been defined sufficiently to be informative (*7, 19*). Protein Sac, an unusual γG1 myeloma protein, has a light chain with an internal deletion of about 70 residues, and a heavy chain lacking the first 102 residues (*20*). The possibility that the findings in the heavy chain are the result of proteolysis has not been excluded. Smithies has proposed a branched-chain DNA for immunoglobulin genes, one that would result in varying deletions dependent on DNA breakage and differing mechanisms of repair (*21*). This could explain the results of the three HCD proteins if codon 216 was particularly susceptible to DNA breakage. The limited number of proteins studied makes any proposed mechanism highly speculative, but future studies may establish the reason for the unusual structure of the hinge region and provide the mechanism by which two, three, or more genes are integrated so that a single polypeptide chain is synthesized.

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4 October 1971; 11 November 1971

Acetylcholine Receptors: Number and Distribution at Neuromuscular Junctions in Rat Diaphragm

Abstract. *The number of acetylcholine receptors per motor end plate in the rat diaphragm, measured by the binding of [^{125}I]α-bungarotoxin, varies directly with rat size and is (4.0 ± 0.2) × 10^7 for full-grown male rats. Autoradiographic analysis of single fibers labeled with this substance reveals that virtually all of these receptors are localized in the end plate.*

α-Bungarotoxin (α-BGT), a polypeptide isolated from the venom of *Bungarus multicinctus*, binds tightly to skeletal muscle and electroplax membranes in the microregion of the acetylcholine receptors and blocks the response of these cells to acetylcholine (ACh) (*1–3*). The polypeptide binds specifically to ACh-sensitive cells (*4*), and both ACh and *d*-tubocurarine compete with α-BGT in the binding reaction (*1, 2*). For these reasons, α-BGT labeled with ^{125}I or ^{131}I is used as a tag for the ACh receptor. We have used [^{125}I]α-BGT to determine the number and spatial distribution of ACh receptors in the muscle membranes at rat neuromuscular junctions.

To determine the number of receptors per end plate, we pinned the left hemidiaphragms of male and female Sprague-Dawley rats (100 to 380 g) to stainless steel grids; in each hemidiaphragm, the endplate region of a layer of deep muscle fibers was exposed by dissecting along the phrenic nerve as it courses through the muscle mass. The pinned diaphragms were incubated for 2 hours at 37°C in modified Ham's F12 culture medium, which was buffered with *N*-2-hydroxyethylpiperazine-*N'*-2-ethanesulfonic acid as zwitterion and contained [^{125}I]α-BGT, 10^{-6} g/ml. Then the diaphragms were transferred to fresh medium that lacked α-BGT, washed with 12 changes of medium for 5 minutes each, fixed in glutaraldehyde, and stained for the end-plate marker acetylcholinesterase (AChE) (*5*). Groups of muscle fiber segments containing 0 to 60 end plates were dissected from the muscle, the number of end plates in each group was determined, and each group was hydrolyzed in 100 μl of 6*N* HCl at 115°C for 48 hours. The hydrolyzates were dissolved and counted by scintillation spectrometry (*6*). Groups of muscle fibers that were free of end plates were analyzed to determine the correction factor for nonspecific binding (which was about 3 percent of total binding).

From 45 determinations on full-grown male rats (345 to 380 g), the number of ACh receptors ([^{125}I]α-BGT binding sites) per end plate was determined to be (3.98 ± 0.21) × 10^7 (mean ± standard error), and the range was (1.14 to 8.70) × 10^7 sites per end plate. Part of this variability is presumably due to variation in the size of individual end plates. The values determined for rats of various sizes are presented in Table 1. From the binding of [^{131}I]α-BGT to whole hemidiaphragms of rats (weight unspecified), Miledi and Potter (*2*) estimated a population of about 4.7 × 10^7 receptors per end plate.

Table 1. Number of ACh receptors (α-BGT binding sites) per motor end plate in rats (N, number of determinations).

Weight (g) and sex	N	Receptors per end plate	
		Mean ± S.E.	Range
110 ♂*	25	$(1.40 \pm 0.05) \times 10^7$	$(0.91–1.86) \times 10^7$
180 ♀*	25	$(2.46 \pm 0.08) \times 10^7$	$(1.71–3.22) \times 10^7$
205–215 ♂♂†	95	$(2.87 \pm 0.10) \times 10^7$	$(1.21–7.12) \times 10^7$
345–380 ♂♂‡	45	$(3.98 \pm 0.21) \times 10^7$	$(1.14–8.70) \times 10^7$

* One rat. † Four rats. ‡ Two rats.

The accuracy of these determinations depends on the purity of the [^{125}I]α-BGT and the accurate determination of its specific activity. We isolated α-BGT from lyophilized venom (Miami Serpentarium) by chromatography on carboxymethyl-Sephadex C-50 and rechromatography on Whatman CM-32 carboxymethylcellulose. The purified α-BGT was iodinated to specific activities of (2.34 to 4.86) $\times$ 10^4 curie/mole (average of one iodine atom per molecule of α-BGT) by the chloramine-T method (*7*), and the iodinated product was purified by chromatography on Biogel P-4 and then on carboxymethyl–Sephadex C-50. Protein concentration was determined by the method of Lowry *et al.* (*8*), which was standardized by amino acid analysis. The amino acid composition agrees with that calculated from the known primary sequence of α-BGT (*9*).

We determined the spatial distribution of ACh receptors by examining the distribution of grains in autoradiographs of rat skeletal muscle fibers. The fibers were treated with [^{125}I]α-BGT, washed, and fixed in glutaraldehyde. Lengths of single fibers were dissected out and mounted on slides, which were then dipped in Kodak NTB-2 emulsion. After developing the exposed emulsion, we determined grain density along the fibers and visualized the end plates by staining for AChE. Figure 1 shows typical autoradiographs of single end-plate regions. In A and B, the end plate is located on the upper surface of the fiber in direct contact with the emulsion. In C and D, the end plate is on one side of the fiber.

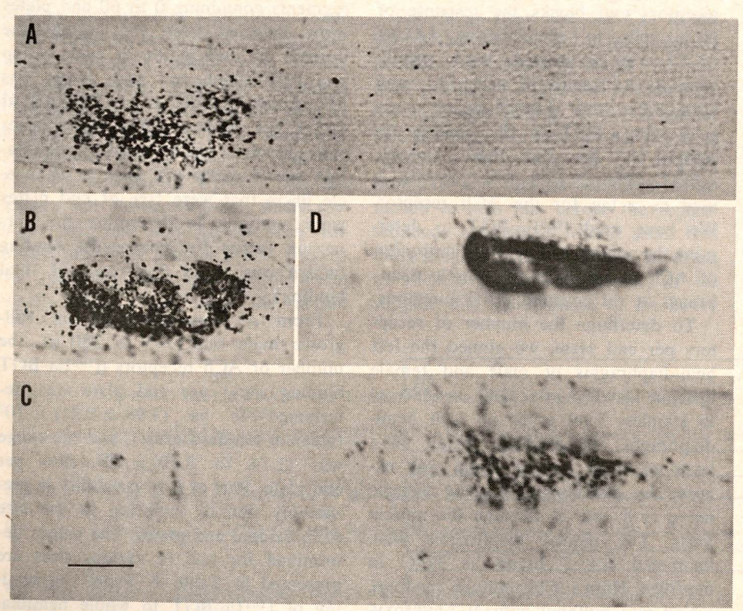

Fig. 1. Autoradiographs of the end plate regions of isolated muscle fibers that had been incubated with [^{125}I]α-BGT. One end plate is shown before (A) and after (B) the preparation was stained for AChE; a second end plate is also seen oriented toward one side of the fiber, before (C) and after (D) staining for AChE. Magnification bars in (A) and (C) represent 10 μm.

The grain distribution (*10*) corresponds quite closely with the synaptic gutters as revealed by AChE staining, and the adjacent muscle fiber surface is comparatively free of grains. From autoradiographs we calculate that in the region outside the end plate but within 130 μm of it, the maximum receptor density is less than 500 sites per square micrometer. Since there may be a small amount of nonspecific binding of α-BGT, we cannot exclude the possibility that there are no ACh receptors outside the end-plate membrane. The estimates of receptor sites per end plate that are based upon grain counts are consistent with the values in Table 1 (although the autoradiographic method is less accurate due to variable sample thickness).

Assuming that the end plate approximates a disk of diameter 25 μm with surface area increased sixfold due to junctional folds (*11*), we estimate the surface area of an average end plate in adult male rats to be about 3000 μm^2. Thus the approximate receptor density in the end plate is 1.3×10^4 receptors per square micrometer. By a comparative autoradiographic method, Barnard *et al.* (*12*) estimated that there are 3.0×10^7 α-BGT sites per end plate and 1.2×10^4 sites per square micrometer for motor end plates in the mouse diaphragm. A similarly dense packing of receptors in postsynaptic membranes in the central nervous system can be inferred from the data of DeRobertis (*13*). In rod outer segments from the retina, where the photoreceptor rhodopsin is most of the membrane protein, receptor density (*14*) is about 2.0×10^4 molecules per square micrometer. By inference motor end plates and other postsynaptic membranes may be constructed largely of receptor molecules. Although accurate data on the surface areas of rat motor end plates are not yet available, it is likely that the receptor density remains fairly constant and that variation in number of receptors per end plate, reported here, reflects heterogeneity in end plate size and enlargement of the end-plate surface area during growth.

We have used [^{125}I]α-BGT in studies correlating receptor density with ACh sensitivity of muscle fibers, measured electrophysiologically. A sensitivity comparable to that at the end-plate (depolarization of several hundred millivolts per nanocoulomb of iontophoretically applied ACh) corresponds to a receptor density of only about 1.5×10^3 receptors per square micrometer of surface in both the nonend-plate regions of adult denervated muscle fibers and in skeletal muscle in tissue culture (*4*). Thus, the receptor density at neuromuscular junctions is much higher than in extrajunctional membranes that are extremely sensitive to ACh. This difference has implications for the appraisal of denervation supersensitivity to ACh and of development and functioning of neuromuscular junctions.

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15. We thank D. Tracey for performing amino acid analysis and N. Joseph for technical assistance. Supported in part by NIH training grant GM–57.

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Morphologic Alterations of Synapses in Electrically Stimulated Superior Cervical Ganglia of the Cat

Abstract. *Prolonged preganglionic stimulation produces marked ultrastructural changes in presynaptic endings, which develop larger zones of contact with postsynaptic dendrites. Profiles of such endings, compared to controls, have fewer synaptic vesicles, similar areas, and greater circumferences. These results are compatible with the hypothesis that synaptic vesicles become incorporated into the plasma membrane during stimulation.*

Biochemical and physiological data suggest that synaptic vesicles may be involved in the mechanism of transmitter release, although direct morphologic evidence is circumstantial (*1*). We investigated the morphology and amount of cholinergic vesicles at neuroneuronal synapses under conditions known to produce marked depletion of neurotransmitter substance. The preparation used was the intensely stimulated superior cervical ganglion of the cat, which had been treated with the drug hemicholinium-3 (HC-3) (*2*). We observed, in addition to changes in numbers of vesicles, unexpected changes in the morphological relation of presynaptic endings to postsynaptic processes in superior cervical ganglia subjected to prolonged electrical stimulation. These data suggest the mechanism of transmitter release that results from stimulation.

Both cervical sympathetic trunks of anesthetized cats were surgically exposed low in the neck, with one side serving as a sham-operated control while the other was placed upon a stimulating electrode. Saline or HC-3 was administered intravenously 5 minutes prior to stimulation. Supramaximal stimulation (as judged by contractions of the nictitating membrane) with monophasic rectangular pulses of 0.3-msec duration and 5- to 10-volt amplitude continued in interrupted trains at 20 to 32 hz for 150 to 190 minutes (*3*). At the end of experiments, stimulation was continued while cats were perfused intraaortically for 10 minutes with an aldehyde fixative (*4*). The ganglia (control and stimulated) were excised, processed simultaneously, and examined by electron microscopy (*5*).

Axodendritic synapses in nonstimulated superior cervical ganglia, in cats treated with saline or HC-3, had a typical ultrastructural appearance. Presynaptic processes were bulbous in shape with a smooth contour, contained spheroidal vesicles, and possessed characteristic membrane specializations (Fig. 1A). Our observations of control ganglia closely agree, qualitatively and quantitatively, with the interrelations reported for axon terminals and dendrites in normal superior cervical ganglia; these interrelations were derived from serial sections examined by electron microscope (*6*).

Visual examination of electron micrographs of synapses in stimulated ganglia, with or without HC-3, disclosed striking alterations in the ultrastructure of a subpopulation of axon terminals (*7*). Profiles of such axon terminals were irregular and crescent-shaped, contained fewer vesicles, had greater zones of apposition with postsynaptic dendrites, and had greater circumferences but similar areas (Fig. 1, B and C). These ultrastructural features apparently resulted from encircling of dendritic profiles by projections of axon endings. In some instances, axon terminals completely encircled dendritic profiles, increasing the zone of apposition to 100 percent. These larger zones of apposition were produced by increases in the nonspecialized portion of the plasma membrane with no obvious increase in the length of synaptic densities. Stimulation did not seem to alter the presynaptic profiles of smallest diameter (0.8 μm).

Measurements were made on electron micrographs in order to specify the extent and frequency of occurrence of the morphological changes. The degree of synaptic apposition for each synapse was expressed as the percentage of the circumference of the dendritic profile in apposition to the axon ending. This measurment was made on random electron micrographs, and frequency distribution histograms were made. The histograms indicated the more frequent occurrence, in stimulated ganglia, of synaptic profiles with a large percentage of the dendritic circumference in apposition to the axon ending. Table 1 shows mean differences between stimulated and control ganglia for this measurement. The effect of stimulation is statistically

Table 1. Effects of electrical stimulation on superior cervical ganglia of the cat. Paired comparison of stimulated and control ganglia in individual cats are given. Samples were approximately 20 to 40 random synapses in each ganglion.

Degree of synaptic apposition: percentage of dendritic circumference in contact with profile of axon ending (mean)			Synaptic vesicles per square micrometer of profile of axon ending (mean)		
Non-stimulated ganglia	Stimulated ganglia	Difference	Non-stimulated ganglia	Stimulated ganglia	Difference
		Saline			
16.87	30.81	13.95	65.0	41.1	23.9
24.63	46.92	22.30	66.0	27.2	38.8
		HC-3 (2 to 5 mg/kg)			
22.95	27.86	4.91	61.1	38.0	23.1
25.31	37.00	11.69	57.7	13.1	44.7
25.29	40.06	14.77	66.3	29.8	36.5
25.00	47.83	22.83	80.0	32.6	47.4
		HC-3 (1 mg/kg)			
24.57	37.86	13.29			
22.77	34.15	11.38			
		Cumulative means			
23.42	37.80	14.39	66.0	30.3	35.7

significant ($P < .004$, based on binomial probabilities) in experiments with saline or HC-3. Similar paired comparisons indicate that circumferences of axon endings in stimulated ganglia (treated with saline or HC-3) were on the average 20 percent larger than those in the respective nonstimulated controls.

To assess the decrease in synaptic vesicles, the number of vesicles in presynaptic profiles was counted and divided by the area of the profile. Table 1 also shows the mean number of vesicles per square micrometer of axon ending for each ganglion and the difference between the means for control and stimulated ganglia for each animal. Stimulation results in a significant decrease in the number of vesicles in animals treated with saline or HC-3 ($P < .02$, based on binomial probabilities). Since similar paired comparisons demonstrated no significant differences in mean areas of presynaptic profiles of the various groups, these measurements indicate that stimulation produces an absolute decrease in the number of vesicles in presynaptic terminals.

These observations made by electron microscopy demonstrate that preganglionic stimulation produces a marked increase in presynaptic axonal plasma membrane. This production of axonal membrane is specifically directed toward postsynaptic dendritic processes, and the added membrane engulfs dendrites and enlarges the zone of apposition between pre- and postsynaptic processes.

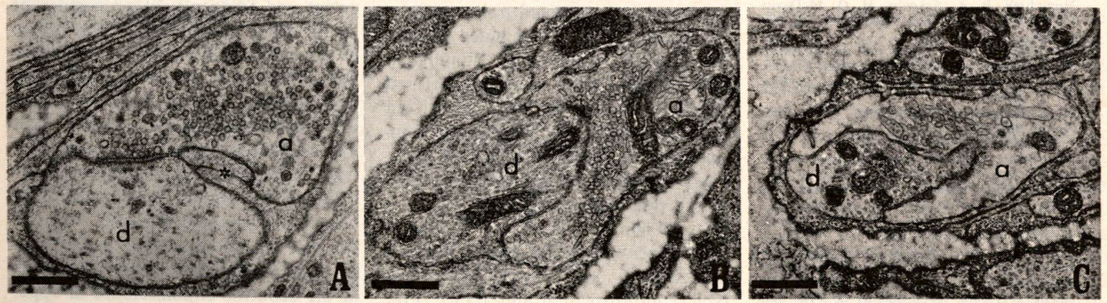

Fig. 1. Electron micrographs of axodendritic synapses in superior cervical ganglia of the cat. A nonstimulated ganglion is seen in A, and stimulated ganglia in B and C (*a*, axon ending; *d*, dendrite; *, cytoplasm of Schwann cell). In stimulated ganglia, with or without HC-3, a subpopulation of axon terminals (B and C) were crescent-shaped, contained fewer vesicles, and had greater zones of apposition with postsynaptic dendrites. Profiles of axon terminals that were more severely depleted of vesicles (C) had clearly greater circumferences but similar areas compared to controls. The bar is 0.5 μm. ($\times$ 21,000)

The resulting increase in the circumference of the axon terminals was not accompanied by a commensurate increase in the area of the profiles. It is unlikely that this apparently directed change in the shape of axon endings without a change in area could be due to a nonspecific mechanism such as simple osmotic swelling. Instead, the production of new membrane must have another explanation. This study correlates an increase in terminal axonal plasma membrane with an absolute decrease in synaptic vesicles (*8–10*). Our initial calculations indicate that the estimated quantity of vesicle membrane lost agrees with the amount of increase of membrane in axon endings, a result suggesting that stimulation produces fusion and incorporation of components of synaptic vesicles into presynaptic plasma membranes (*11*).

In stimulated ganglia that were treated with saline, we observed a 48 percent depletion of synaptic vesicles, which correlated closely with a 45 percent decrease (below initial levels) in contractions of the nictitating membrane. In contrast, in stimulated ganglia that were treated with HC-3, we observed a 59 percent depletion in vesicles but a considerably larger (98 to 99 percent) reduction in response of the nictitating membrane. Prolonged stimulation coupled with the administration of HC-3 produces a progressive decrease in the size of transmitter quanta, as judged by declines in the amplitude of miniature end-plate potentials (*12*). Therefore, the greater reduction in synaptic transmission in stimulated ganglia treated with HC-3 may be due to incomplete charging of vesicles with acetylcholine.

Thus, our data provide further evidence for a "vesicle hypothesis" (*9, 13*) and suggest that transmitter is released by exocytosis with at least temporary incorporation of vesicle components into plasma membranes (*14*).

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4. Fixation consisted of perfusion with a mixture of phosphate-buffered glutaraldehyde and formaldehyde followed by soaking of slices for 1 hour at 4°C in the same fixative and then postfixing in 1 percent O_sO_4. After slices were dehydrated in ethanol and embedded, large ultrathin sections were cut in the transverse plane.
5. Electron micrographs were systematically taken with a Siemens Elmiskop IA by recording fields at the corners of grid openings. For morphometric measurements, a series of random electron micrographs were assembled, and all axodendritic synapses that showed characteristic membrane densities were evaluated. Profile circumferences were measured with a map measurer, and profile areas with a planimeter.
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Carbon Monoxide Concentration Trends in Urban Atmospheres

Carbon monoxide is a pollutant of urban air that has recently begun to attract increased attention (*1*). Although the concern about this gas at present is associated with vehicular exhaust, CO is not a new pollutant in man's environment. It is always produced during incomplete combustion and has long been artificially present in man's environment.

A number of studies of CO concentrations in the air of New York City have been made during the last 50 years (*2–6*). For purposes of comparison, the data of Table 1, which summarize the results of studies made between 1922 and 1967, are limited to those locations in the city at which vehicular traffic is heaviest. According to these data, the CO concentration near busy thoroughfares and intersections in New York City is not increasing and may actually have decreased since 1922.

The predominant modern source of CO is the exhaust gases from the internal-combustion engine. Approximately 97 percent of the CO in the air of New York City is currently attributable to this source (*7*). Prior to the advent of the internal-combustion engine, the major source was fuel burning for space heating, water heating, cooking, and the production of electrical energy. The types of fuel consumed in New York City during the past several decades have changed radically, the predominant shift having been from coal and manufactured gas (*8*) to oil and natural gas. The exhaust gases from the combustion of fuel oil and natural gas do not contain CO in significant amounts. The various fuels consumed in New York City during 1934 and 1965 are shown in Table 2 (*2, 9*).

Concurrently with changes in the types and amounts of fuel being burned, there have also been improvements in the combustion efficiencies of heating units. The coal- and wood-burning stoves that were present in many individual apartments 50 years ago have been replaced by larger, more efficient boiler units that provide heat and hot water for entire apartment buildings. Moreover, the coal furnaces that provided heat for tens of thousands of New York's private homes a half century ago have been replaced with oil or gas furnaces.

As an example which illustrates such changes in fuel consumption patterns and the corresponding reduction in CO emissions, let us consider the effect of the elimination of anthracite coal as a space heating fuel in one- and two-family dwellings. In 1934, 4.6×10^6 tons (4.1×10^6 metric tons) of anthracite were burned in such structures in New York City for space heating purposes (*9*). If we assume that 1 pound (454 g) of coal requires 8 pounds of air to produce 13,000 Btu (51,500 kcal) of heat (*10*), and that flue gas from coal-burning dwellings is approximately 1 percent CO (*11*), we estimate that 400,000 tons of CO were emitted from the one- and two-family dwellings that burned coal in 1934. The vehicular

Table 1. Carbon monoxide concentrations in New York City streets from 1922 to 1967.

Year	CO concentration (ppm)	Sampling condition	Reference
1922	100	Moderate-heavy traffic	(*5*)
1932	Range, 2–129; average, 32	Heavy traffic (average: 1900 cars per hour)	(*6*)
1966	Peak hourly average range, 19–95; average, 32	In-traffic sample, very heavy traffic	(*2*)
1967	Hourly average range, 1–17; average, 8	45th St. and Park Ave., continuous samples, heavy traffic flow (1000 to 3400 vehicles per hour)	(*3*)

Table 2. Consumption of the principal fossil fuels in New York City during the years 1934 and 1965.

Year	Anthracite coal ($\times 10^6$ tons)	Bituminous coal ($\times 10^6$ tons)	Fuel oil ($\times 10^6$ gallons)	Natural gas* ($\times 10^9$ cubic feet)	Manufactured gas* ($\times 10^9$ cubic feet)
1934	10.6	9.1	611	None	54
1965	0.72	5.4	4086	167	None

* One cubic foot equals 0.028 m^3.

emissions of CO in the five boroughs of New York City are currently estimated to be 1.4×10^6 tons, whereas the total CO emissions from all space heating sources are at present only 20,000 tons (*7*). Thus, in 1934 this single source, 4.6×10^6 tons of anthracite, contributed about 30 percent of the quantity of CO presently being emitted from vehicular sources. The total coal consumption in 1934 was 10.6×10^6 tons of anthracite and 9.1×10^6 tons of bituminous.

The CO emissions from automobiles in New York City in 1934 are difficult to estimate. Gasoline consumption in the metropolitan area, which includes New York City and nearby counties in New York, New Jersey, and Connecticut, was about 525×10^6 gallons (1980×10^6 liters) in 1934, as compared to 2.1×10^9 gallons in 1969. Because of the relatively greater growth in the suburban counties, a larger fraction of the gasoline is undoubtedly now purchased and used in the suburban counties rather than within the city. The only available figures for gasoline consumption for the years 1934 and 1969 are those which include Nassau, Suffolk, Rockland, and Westchester counties, in addition to New York City. Also, increased emissions due to the greater quantities of gasoline now being consumed are partly offset by the higher combustion efficiency of contemporary engines (*12*). The higher concentrations of CO in the air of New York City in 1934 could undoubtedly be explained fully if data were available on other sources of this gas whose outputs have since diminished or been eliminated.

This historical trend may be similar to that in other cities in climates that require space heating, but Paris is the only other large city for which we have been able to find comparable data. In 1928, Cambier and Marcy (*13*) reported CO concentrations in the streets of Paris that ranged from 40 to 60 parts per million (ppm). In a report by Labonde and Menetrier (*14*) of measurements made during the period from 1959 to 1964, it was reported that the hourly concentration of CO exceeded 10 ppm only 91 times in the 6 years of the study.

A discussion of the concentrations of CO to which human beings have been exposed in past years would not be complete without the inclusion of a number of indoor sources of CO that no longer exist. For example, the use of manufactured gas, which was discontinued in New York City in 1956, was the cause of several hundred accidental deaths per year, in addition to a considerable number of suicides. Deaths due to accidental exposure to CO in New York City have diminished over the years, from a peak of 379 in 1945 to an average of three per year during the past 5 years (*15*). The number of sublethal cases of acute CO intoxication is presumed to have been very much larger than the number of fatalities, and it can also be assumed that relatively high exposures which did not produce symptoms of acute intoxication occurred with some degree of regularity, but there are no data on this aspect of the problem. Badly adjusted ventilation systems and leaking gas fixtures were the main causes of excessive indoor exposure to CO.

It is possible that even higher concentrations of CO in the air prevailed in past times under more primitive conditions of living, but very few data are available. A recent report from New Guinea (*16*) shows that the concentration of CO in the huts (indoor fires are used for space heating) averages 21 ppm, with peaks as high as 150 ppm. Thus, although CO from relatively advanced technology is a ubiquitous contaminant of the modern environment, it is very possible that the concentration of this gas in the air we breathe is now lower than at any time since man first learned to use fire.

Lewin (*17*) traced the early history of CO poisoning and concluded that this poisoning "of all, stands alone in its close relation to the history of the civilization of mankind." Among the many examples given by him, he cites Julian the Apostate (A.D. 331–363), who was almost asphyxiated because he had a small fire brought into his room. We believe that the dangers from badly ventilated indoor stoves are well known to many Americans. No data on Japanese homes in which the hibachi is used for heating have come to our attention, but they would be of interest in this regard.

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11 January 1972

Meetings

Translation: Its Mechanism and Control

The purpose of a meeting on Translation, Its Mechanism and Control, held in November 1971 under the auspices of the Fogarty International Center at the National Institutes of Health, was to examine present understanding of protein biosynthesis, to reach a consensus, and to base upon that a uniform system of nomenclature for the variety of factors involved in protein biosynthesis. In this respect, the conference was highly successful, and general agreement was obtained to employ the system of nomenclature for the protein synthetic factors which is indicated in Table 1; references (*1–13*) indicate the correspondence to some earlier terminologies. The nomenclature is more complete for prokaryotic than for eukaryotic systems, and is more certain for factors involved in polypeptide chain elongation than for those required at initiation and termination. The reasons for this can be indicated by a summary of the discussions of protein formation and translational control.

Initiation and the ribosome cycle. In bacterial systems, binding of formylmethionyl-transfer RNA (fMet-tRNA), which is the initiator tRNA, to ribosomes is directed by the initiator codon, AUG (adenosine, uridine, guanosine). This process and subsequent steps up to formation of the first peptide bond require at least three special protein factors [IF-1, IF-2, IF-3 (Table 1)]. The exact roles of these factors are not known, but a number of their activities have been identified.

The IF-1 (molecular weight, 9,000) participates with IF-2 and guanosine triphosphate (GTP) in fMet-tRNA binding to ribosomes; it can bind 30*S* ribosomes but is apparently released when the 50*S* ribosome joins to form the 70*S* initiation complex. The IF-2 has been isolated in two forms (molecular weight, 80,000 and 100,000); both can function with IF-1 and GTP. The IF-2 is bound to an initiation complex formed in presence of [α,β-methylene]-GTP, but not to complexes formed in presence of GTP. This suggests that hydrolysis of GTP results in release of IF-2 from the initiation complex.

Hydrolysis of GTP is also required for formation of the first peptide bond, the reaction that finishes the initiation process. This GTP hydrolysis is not accompanied by advance of the messenger RNA (mRNA) along the ribosome, suggesting that both fMet-tRNA and the initiating AUG codon may be already bound directly to the peptide-holding (P) site on the ribosome.

The role of IF-3 is less clear. At high concentrations of template, IF-3 is not required for AUG-directed fMet-tRNA binding or for polyphenylalanine formation directed by polyuridylic acid [poly-(U)]. However, IF-3 *is* required at limiting concentrations of these templates, and for any translation of phage mRNA. Greater template specificity is suggested for subfractions of IF-3. At least two forms have been separated by DEAE chromatography; one stimulates translation of both MS-2 (a phage) mRNA, the other preferentially stimulates late T4 (a phage) mRNA translation. The two forms also seem to show different preferences for initiation of translation of the MS-2 coat and RNA synthetase cistrons.

The initiation factors also appear to interact with one another. For example, IF-3 stabilizes the complex of IF-2, GTP, and fMet-tRNA. Even more complex are the reactions of the initiation factors with the ribosome. The IF-3—or more precisely, one of its subfractions—dissociates 70*S* ribosomes to 30*S* and 50*S* particles (or, alternatively, holds the subunits apart). It also affects the sedimentation rate of the ribosomes, perhaps because it binds to the 30*S* but not to the 70*S* particle. The IF-1 seems to enhance the dissociating activity of IF-3.

Partially because of the uncertainty of the sequence of reactions involving IF-3, the mechanism and significance of ribosomal dissociation remains incompletely understood. While 70*S* ribosomes in cells seem to exchange 30*S* and 50*S* subunits, the mechanism of exchange is still unclear. In one view, ribosomes are released as 70*S* couples and are then separated by the action of IF-3. In an alternative view, ribosomes are released as subunits and then either join in new 70*S* couples or are held apart by factor IF-3 and reenter polysomes. In the former, free 70*S* ribosomes are an obligate feature of the ribosome cycle; in the latter, they are a side path used in conditions of suboptimal protein synthesis. The results obtained (that is, association or dissociation of ribosomes) depend on the exact environmental conditions and on preparative and analytical methods. Thus, the stability of ribosome couples is affected by the binding of various tRNA derivatives or tRNA itself at different

Table 1. Uniform nomenclature for translation factors.

Factors*	Abbreviation†	Nomenclature replaced
	Prokaryotic factors	
Initiation factor 1	IF-1	F1 (*1*), A (*2*), FI (*3*)
Initiation factor 2	IF-2	F2 (*1*), C (*2*), FIII (*3*)
Initiation factor 3	IF-3	F3 (*1*), B (*2*), FII (*3*)
Elongation factor Tu	EF-Tu	Tu (*4*), FI_u (*5*), S_u (*6*)
Elongation factor Ts	EF-Ts	Ts (*4*), FI_s (*5*), S_1 (*6*)
Elongation factor G	EF-G	G (*4*), FII (*5*), S_2 (*6*), translocase (*7*)
Release factor 1	RF-1	R (*8*), R1 (*9*)
Release factor 2	RF-2	R2 (*9*)
Release factor 3	RF-3	α (*10*), S (*11*)
	Eukaryotic factors	
Elongation factor 1	EF-1	Transferase I (*12*), TF-I (*13*)
Elongation factor 2	EF-2	Transferase II (*12*), TF-II (*13*)

* Where necessary, species may be indicated in adjacent parentheses, for example, EF-G (*Escherichia coli*). † Abbreviations should be used only where their meaning is clear, otherwise the full term shall be used.

sites on the ribosome. Unanimous agreement with respect to the pathway involved in initiation of the ribosome cycle awaits a more uniform approach to this problem.

Initiation and other possible sites of translational control. Because of convenience and ample physiologic data, translational controls have been studied most intensively in prokaryotic systems with the use of phage mRNA's. One well-established mechanism of translational repression is the repressor-like effect of phage coat protein on f2 and Qβ phage replicase synthesis. In a model that seems to have potentially wider applicability, bacteriophage infection introduces a defect in the ability of the hosts' ribosomes to initiate translation of at least certain mRNA's. Discrimination—for example, initiation of late T4 mRNA but not MS-2 RNA—is suggested by several experiments and may be connected with the existence of the several forms of IF-3; but the results from all laboratories are not in accord. In addition, an antibiotic inhibitor of initiation, kasugamycin, preferentially inhibits the translation in vivo and in vitro of the bacteriophage f2 maturation protein cistron, compared to translation of the coat protein cistron. Again, interaction with initiation factors may be involved. An additional bacterial protein apparently affects initiation specifically by complexing with IF-3; as a result, translation of MS-2 RNA but not of T4 mRNA is inhibited.

With respect to higher organisms, there have been recent successes in the cell-free translation of eukaryotic mRNA's in eukaryotic systems. These systems often cross species barriers successfully. Globin, encephalomyocarditis virus, and lens crystalline protein mRNA's are translated in systems derived from Krebs II ascites cells as well as from rabbit reticulocytes. While these in vitro results suggest an absence of translational discriminatory controls in higher organisms, control of translation in vivo might be expressed quite subtly. For example, there seems to be a different rate of initiation on mRNA's corresponding to the α and β chains of rabbit hemoglobin. A specific factor isolated from avian muscle ribosomes (and again possibly comparable to the prokaryotic initiation factor IF-3) is required for translation of avian myosin mRNA in a cell-free system derived from rabbit reticulocytes. Small molecules also seem to affect the specificity of initiation. For example, altering the Mg^{2+} concentrations in extracts can induce Krebs II tumor cell ribosomes to discriminate between the translation of globin and viral mRNA's; as another example, heme has a stimulatory effect on globin biosynthesis.

Polypeptide chain elongation. In contrast to the initiation step, relatively complete studies with pro- and eukaryotic elongation factors have defined a series of partial reactions involving the required soluble elongation factors EF-Ts, EF-Tu, and EF-G (Table 1). Elongation factor Tu is a protein with a molecular weight of approximately 42,000. This protein binds GTP and aminoacyl-tRNA in a stepwise manner. The ternary complex thus formed reacts with ribosomes, transferring the aminoacyl-tRNA to the binding or A site of the ribosomes and releasing inorganic phosphate (P_i) and the binary complex of EF-Tu·GDP. This is the binding or codon recognition reaction. EF-Tu is inactive while associated with guanosine diphosphate (GDP). The EF-Ts, a second protein, then displaces GDP to form an EF-Ts·Tu complex, and in turn, is displaced by GTP to regenerate EF-Tu·GTP. Thus, EF-Ts catalyzes the exchange of GDP and GTP on EF-Tu, regenerating the active EF-Tu·GTP complex.

The third bacterial elongation factor, EF-G, is also a protein and has a molecular weight of about 73,000. It effects elongation after the ribosomal enzyme peptidyl transferase has catalyzed the formation of a peptide bond between the nascent peptidyl-tRNA and the oncoming aminoacyl-tRNA. Both EF-G and GTP are thought to be required during translocation of the newly formed peptidyl-tRNA and mRNA from A to P sites on the ribosome. In this partial reaction, as in the binding reaction, hydrolysis of GTP occurs.

Both EF-G and GTP also function in the release of deacylated tRNA from the P site of the ribosome. Furthermore, the interaction of EF-G and GTP with the ribosome can be studied in the absence of protein synthesis. When these components are mixed, there is catalytic hydrolysis of GTP. Much of this may result from repeated binding and release of the EF-G from the ribosome. When the antibiotic fusidic acid stabilizes a complex formed between EF-G, ribosome, and GDP, there is hydrolysis of only one molecule of GTP for each ternary complex formed.

The EF-Tu–mediated guanosine triphosphatase activity can also be uncoupled from chain elongation. This occurs, for example, in the presence of the antibiotic sparsomycin. The function of GTP hydrolysis, the mechanism of coupling of the various partial reactions, and the precise mechanism of translocation remain unknown. However, several interesting clues have been obtained. First, thiostrepton and related antibiotics can inhibit both EF-G–mediated and EF-Tu–mediated hydrolysis of GTP. Second, removal of two specific acidic proteins of the 50*S* ribosome—each with a high helical content and molecular weight of approximately about 13,000—suppresses guanosine triphosphatase activities of both EF-Tu and EF-G. Both activities are restored when either of the two proteins is added to the depleted ribosome. These results are consistent with an overlap of sites for function of EF-G and EF-Tu, or a single site for the hydrolysis of GTP by these two factors during protein synthesis. The precise extent of GTP consumption during amino acid incorporation has not yet been determined.

In eukaryotic systems, EF-1 appears to have the properties of the bacterial EF-Tu in binding aminoacyl-tRNA to the ribosome. Whether EF-1 contains a subunit corresponding to EF-Ts, or whether no EF-Ts is required in eukaryotic cells, is unclear. Several chromatographic subfractions of EF-1 that may be relevant were reported. The EF-2 is directly analogous to the prokaryotic EF-G.

Chain termination. With regard to codon-specific release of polypeptides from ribosomes, prokaryotic systems seem to be able to utilize two protein factors, RF-1 or RF-2, with a third, RF-3, acting to stimulate the reaction. The RF-1 mediates release in response to the termination codons UAG and UAA, and RF-2 in response to UAA and UGA. There is some confusion with respect to RF-3, with some evidence relating it to the elongation factor, EF-Tu, and other evidence suggesting that it is distinct.

In contrast, in mammalian cells, a single protein fraction seems to embody all the requisite functions. Furthermore, the mammalian factor shows a specific requirement for GTP, a need not yet demonstrated in bacterial termination. The mechanism in the two systems may yet be similar in both; ribosomal peptidyl transferase can carry out hydrolysis of the polypeptide chain from tRNA in the absence of any release factor activity. This enzymatic site may therefore be involved in the normal mechanism of chain termination (*14*).

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Ethics, Law, and Genetic Counseling

Genetic counseling has moved out of its childhood, into a period of fast-growing adolescence. Advances in genetic knowledge, increased public demand, and refinements in amniocentesis help account for the sudden spurt. But what are its goals, and what ought the means to be?

That was the general theme of an international conference on "Ethical Issues in Genetic Counseling and the Use of Genetic Knowledge," held at Airlie House, Warrenton, Virginia, 12 to 14 October 1971, where 85 participants from six countries met. The interdisciplinary conference, cosponsored by the Institute of Society, Ethics and the Life Sciences and the John E. Fogarty International Center, National Institutes of Health, sought to explore the ethical dilemmas of genetic counseling in their philosophical, scientific, legal, sociological, and political ramifications.

While one must expect arguments in a conference of this kind, the tenor was not that of unbridled disputation. Instead, it was one of serious perplexity and a recognition that the difficulty of the central questions sorely strains the limits of present knowledge, scientific technique, and cultural wisdom. This mood was exemplified in the opening address, given by T. Sonneborn (University of Indiana). He noted that, while the conference brought together scientists and representatives of the humanities and social sciences, no simple polarity can be established between the two groups. The scientists disagree among themselves on the issues no less than the philosophers, lawyers, and social scientists. "Who or what decides what is right or good? By what authority? What do we really mean when we ask about anything: 'Is it ethical?' " On questions of this kind, Sonneborn noted, there is neither certainty nor uniformity of opinion. "Humility and compassion" are imperative in the face of ethical complexity, he said.

After Sonneborn's address, the conference moved systematically through a number of problems, beginning with a series of papers on the present scope of genetic counseling and the variety of dilemmas presented to the counselor. F. C. Fraser (McGill University) presented data to show that, in at least one large and perhaps not untypical counseling center, most of the problems presented (usually on referral) deal with the question "Will it happen again?"—that is, will there be a recurrence of some disease or defect already known to exist in a family? The range of conditions presented is very wide, totaling 349 at the center analyzed by Fraser. Of that number, 61 were either sex-linked or diagnosable in utero, making the possibility of amniocentesis a relevant consideration. Accurate diagnosis, Fraser noted, is the first step in the counseling process, followed by a determination of the probability of recurrence, and concluding with assistance by the counselor in helping the family to reach a decision.

If it is often difficult for patients to know what to do, the pressures on the counselor are often no less. Sometimes the counselor is stymied by an inability legally to get pertinent data from hospital records. At other times, as M. W. Shaw (University of Texas) stressed, de facto and de jure obstacles stand in the way of options available to the counselor or to the family (for example, local antiabortion statutes). "The right of privacy," in particular, poses some acute dilemmas, a theme developed by both Shaw and H. A. Lubs (University of Colorado Medial Center). The law does not require an individual to make known the fact (if he has discovered it) that he harbors a deleterious gene; nor does it require that a physician inform other family members. But should it? Lubs presented a number of case histories to show how painful the dilemmas of privacy can be even at present; and they may increase as nationwide genetic data banks are established.

Another cluster of dilemmas facing the counselor turns on different theories and styles of counseling individual patients. J. Hall (Johns Hopkins Hospital) noted that the traditional role of the counselor has been that of "neutral educator," essentially doing no more than presenting patients the odds and the facts. But this concept faces increasingly heavy weather, particularly because of the rapidly expanding range of options. Not surprisingly, these developments have led to disagreements among counselors about the kind of stance they should take toward their patients. J. R. Sorenson (Princeton University), in a sociological survey of decision-making in counseling practice, noted that, however much the value of neutrality on the part of the counselor may be espoused, counselors do in fact often make decisions for their patients, or at least heavily influence the decisions by the way they present data. J. Fletcher (Ecumenical Training Center) came to a similar conclusion in his findings on

the actual practices of counselors when their interactions with patients are carefully observed.

These dilemmas are not likely to disappear in the near future. As J. W. Littlefield (Massachusetts General Hospital) noted in a paper on the status and problems of amniocentesis and prenatal diagnosis, the number of inherited metabolic disorders presently or potentially diagnosable in utero continues to grow. More individuals will be determined to be at risk for genetic disease, and more fetuses will be diagnosed as defective. What, then, should the response of society be to genetic disease and defect?

A. Motulsky (University of Washington), in a paper on the significance of genetic disease from a patient perspective, developed the point that the concept of "normal" and "abnormal" is statistical rather than philosophical, and that even with given defects (such as Down's syndrome) the range of variation in expression can be wide. J. F. Crow (University of Wisconsin Medical School) contended that, from the perspective of population genetics, the minute number of individuals receiving genetic counseling makes the statistical impact negligible. However, assuming an increase in genetic counseling and knowledge, Crow also argued that we are not nearly so ignorant of long-range possibilities as many would contend. In particular, it is possible to predict relaxed natural selection, comparatively little gain to selection even with abortion of all fetuses carrying one or more mutant genes, only a 50 percent change in traits even with full reproductive compensation, and an increasingly important role for mutation as a component of genetic disease. Crow's key point was that, in dilemmas pitting individual welfare against the genetic welfare of the species, it is still reasonable to give the benefit of doubt to individuals.

The Motulsky and Crow papers led the conference into discussion of the deepest and most troubled ethical issues. D. Callahan (Institute of Society, Ethics and the Life Sciences) considered the significance of genetic disease from a philosophical perspective. He observed that society has taken many centuries to develop a sensitive, receptive response to the defective person; that gain should not be jeopardized by new-found powers to ameliorate defectiveness. D. Brock (Edinburgh University, Scotland) pointed out that words such as "abolish," "eliminate," "eradicate," and "conquer," when used with respect to genetic disease, carry with them the danger of apocalyptic visions and correspondingly coercive, draconian solutions—approaches incompatible with the need to develop genetic counseling "as an expression of man's humanity to man."

The question of what it means for human beings to treat each other humanely was at the center of the papers specifically devoted to ethical issues. J. Gustafson (Yale University), in an "ethical overview," urged that while a pluralism of values in our society makes a consensus on particular ethical issues unlikely, it might be possible (and highly desirable) to reach some minimal social agreement on at least what consequences should be avoided in the development of genetic counseling and the use of genetic knowledge. (The papers and resulting discussion at the conference suggested, for instance, a strong consensus against coercive strategies.) Robert F. Murray, Jr. (Howard University Medical School) contended that, even in mass screening programs, the welfare and freedom of individuals or couples should always come first. A similar note was struck by M. Kaback (Johns Hopkins Medical School) in his description of the goals of a large Tay-Sachs screening program in the Baltimore area. Indeed, Murray and Kaback agreed that it is probably unethical to even mount screening programs unless there exist specific therapeutic alternatives for patients and carriers.

P. Ramsey (Princeton University) pressed the ethical issues still further, arguing that care must be taken, particularly in the techniques of prenatal diagnosis, not to infringe the minimal ethic of medicine, "do no harm." Moreover, if this principle is taken seriously, it should include a consideration of the fetus as well as that of the mother. The ethical principle of the "greatest good to the greatest number," which many use as their fundamental ethical axiom, has a major drawback. It does not allow one to compare the depth of harm to a few with the breadth of benefits to the many; thus a critical ethical dilemma is ignored.

At the heart of the sessions devoted to ethical issues were three papers on "the right of life," by H. D. Aiken (Brandeis University), L. R. Kass (National Academy of Sciences), and R. S. Morison (Cornell University). Aiken developed a philosophical argument to show that no right could be absolute, including the right to life. Moreover, he held, any judgment concerning the right to life of an individual must be judged in the context of the possibility of that individual's being able to exercise a wide range of other rights. In the absence of that latter possibility, the right to life becomes empty and may be set aside.

Kass centered his discussion on the ethical issues raised by abortion of "defective" fetuses. The central question, as he phrased it, turns on the belief in the radical equality of all human beings, defective or not, an equality which presumes certain fundamental rights, including the right to life. The very language often used in talking about defectives may be prejudicing individual cases—for instance, when one says "the fetus is a Down's" rather than "the fetus has Down's syndrome." Dangerous and dehumanizing attitudes can easily develop. Kass's line of argument laid heavy stress on the need to develop or to recognize a "natural standard" for making ethical decisions. R. S. Morison countered by pointing out the primacy of society's interest in the quantity and quality of the children who are, or will be, born. Moreover, the use of society as a standard, instead of a natural standard, by no means entails a descent to totalitarianism or brute coercion.

These papers formed the backdrop for the ensuing papers on law and public policy. The Honorable Lord Kilbrandon (Scottish Law Commission) presented a rich sketch of the comparative laws of different nations as they apply to genetic counseling and related issues. C. Fried (Harvard Law School), in a response to Lord Kilbrandon's paper, pointed out the need for a philosophical anthropology which would better enable the public, professionals, and legislatures to deal more adequately with the complicated questions of rights and obligations being raised by advances in the "new biology." A. Capron (Yale Law School) developed the position that, while parents have a legal right to be fully informed decision-makers about whether to have a child, this right operates in the counseling situation independently of any moral conclusions. In addition, Capron argued that there is no necessary connection between legal and moral rights. A defective child, for instance, may have a moral claim against its parents for bringing it into the world; but, Capron argued, such a claim would be much too far-reaching if made a legal rule.

The final set of papers dealt with the establishment of social and scientific

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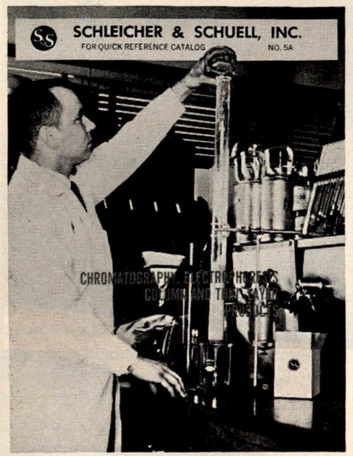

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priorities and with the development of mechanisms for public policy decision-making. J. V. Neel (University of Michigan Medical School), after sketching a number of present and potential genetic developments, presented four possible criteria for setting priorities: reduction of the proportion of persons with genetic disease, improvement of the expression of existing genotypes, creation of genetically superior individuals, and protection of the present gene pool by a world population policy. His conclusion is that we are not yet scientifically, ethically, or socially in a solid enough position to make wise choices among the possible priorities.

The conditions for achieving the necessary kind of consensus for deciding on priorities and for public policy-making were analyzed by D. A. Kindig and V. W. Sidel (Montefiore Hospital; Einstein College of Medicine) and by H. P. Green (George Washington University Law School). The former paper pressed for a more complete relating of genetic problems to other social issues and priorities in society. The need for better social and political processes to carry this out is evident, they said. Kindig and Sidel agreed with Green that decisions in this area must be made by an informed public and not by elite groups. This point was underscored by D. Eaton (All Soul's Unitarian Church, Washington, D.C.), who noted that genetic disease is a much greater preoccupation with whites than with blacks. In addition, Green contended that, if the public is to have genuine options and to become fully informed, there must be public debate and a resort to the adversary system. This method does not always guarantee truth or wisdom, but it does facilitate open discussion, a minimum necessity for wise public decision-making. K. Ludmerer (Johns Hopkins Medical School) stressed, in this context, the importance of public education for an understanding of the capabilities as well as limitations of science.

Where is the future likely to take us in genetics? This question, which kept surfacing throughout the conference, was directly confronted by R. L. Sinsheimer (California Institute of Technology), who asked whether future scientific developments are an "ambush or opportunity"? His clear answer was "opportunity," even if laced with dangers. Higher states are possible for the human species, intellectual, emotional, and moral; the price of not pursuing them would be "to stagnate in fear and doubt." J. V. Neel responded from the floor that he did not agree with Sinsheimer's thesis. Others agreed in part and objected in part. That typified the entire conference.

D. CALLAHAN
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27–29. **Red Cell Metabolism and Function**, 2nd intern. conf., Ann Arbor, Mich. (G. F. Brewer, Dept of Human Genetics, Univ. of Michigan, Ann Arbor 48104)

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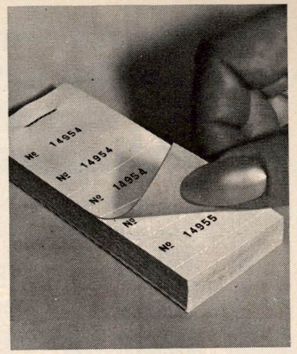

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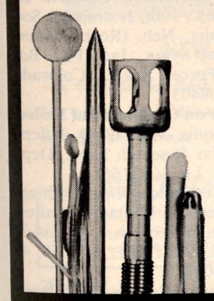

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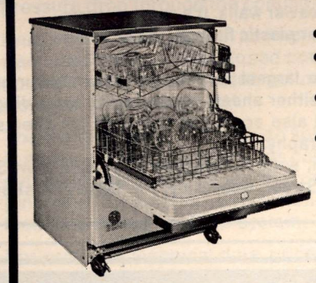

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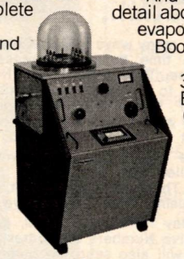

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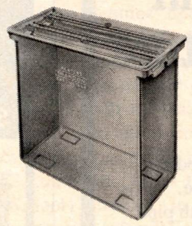

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For more information, write for Bulletin L383, Shandon Southern Instruments, Inc., 515 Broad Street, Sewickley, Pa. 15143 (Pittsburgh District).

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Dame. (J. D. Webster, Hanover College, Hanover, Ind. 47243)

28–29. Society for **Investigative Dermatology**, Atlantic City, N.J. (J. S. Strauss, Boston Univ. Medical Center, 80 E. Concord St., Boston, Mass. 02118)

28–29. Nebraska **Acad. of Sciences**, Lincoln. (C. B. Shultz, 101 Morrill Hall, Univ. of Nebraska, Lincoln 69508)

28–29. South Dakota **Acad. of Science**, Aberdeen. (W. L. Hoffman, Dept. of Physics, Univ. of South Dakota, Vermillion 57069)

28–29. Illinois State **Acad. of Science**, Macomb. (N. R. Brewer, ISAS, 5757 Drexel Ave., Chicago, Ill. 60637)

28–29. **Pests and Pesticides**, Missouri Acad. of Science, Cape Girardeau. (H. D. Rutledge, Dept. of Physics, Southeast Missouri State College, Cape Girardeau 63701)

28–30. Wisconsin **Acad. of Sciences, Arts and Letters**, Stevens Point. (J. P. Batt, 5001 University Ave., Madison, Wis. 53705)

28–30. American Acad. of **Psychoanalysis**, Dallas, Tex. (Mrs. C. Bruskin, 40 Gramercy Park North, New York 10010)

29. American College of **Psychiatrists**, Dallas, Tex. (P. A. Martin, 857 Fisher Bldg., Detroit, Mich. 48202)

29. **Synthetic Fibers**, 9th annual symp., American Inst. of Chemical Engineers, Tidewater-Virginia Section, Williamsburg, Va. (C. E. Armengol, E. I. du Pont de Nemours & Co., Inc., P.O. Box 27001, Richmond, Va. 23261)

30–1. American Soc. for **Clinical Investigation**, Atlantic City, N.J. (P. Calabresi, Roger Williams General Hospital, Providence, R.I. 02908)

30–4. **Environmental Progress in Science and Education**, Inst. of Environmental Sciences, New York, N.Y. (Technical Program Committee, IES, 940 E. Northwest Highway, Mount Prospect, Ill. 60056.

30–4. **Experimental NMR** Conf., 13th, Pacific Grove (Monterey), Calif. (B. L. Shapiro, Dept. of Chemistry, Texas A&M Univ., College Station 77843)

May

1. Society for **Applied Anthropology**, Montreal, P.Q., Canada. (T. Weaver, Dept. of Anthropology, Univ. of Arizona, Tucson 85721)

1–3. Rocky Mountain **Bioengineering** Symp., 9th, and **Biomedical Sciences Instrumentation** Symp., 10th, Instrument Soc. of America, Omaha, Neb. (Rocky Mountain Bioengineering Symp., Inc., P.O. Box 59, U.S. Air Force Acad., Colorado Springs, Colo. 80840)

1–3. Conference on **Chemical and Molecular Lasers**, St. Louis, Mo. (W. Q. Jeffers, McDonnell Douglas Research Labs., Dept. 223, Bldg. 34, St. Louis 63166)

1–3. **Offshore Technology** Conf., 4th annual, American Inst. of Mining, Metallurgical, and Petroleum Engineers, Houston, Tex. (A. R. Scott, AIMMPE, 345 E. 47 St., New York 10017)

1–4. **Environmental Progress in Science and Education**, Inst. of Environmental Sciences, New York, N.Y. (K. Dambach, IES, 940 E. Northwest Hwy., Mount Prospect, Ill. 60056)

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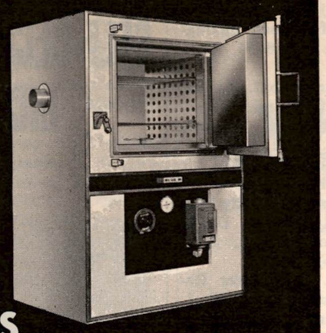

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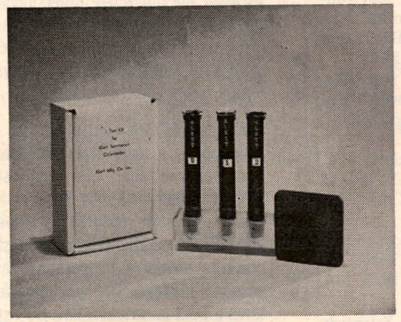

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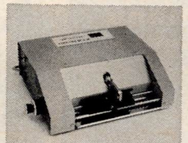

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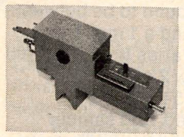

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1–5. American **Psychiatric** Assoc., Dallas, Tex. (W. E. Barton, 1700 18th St., NW, Washington, D.C. 20009)

2–5. Virginia **Acad. of Science**, Lexington. (B. M. Bruner, P.O. Box 8454, Richmond, Va. 23226)

2–5. **Titanium**, 2nd intern. conf., American Soc. for Metals, Metallurgical Soc., and Inst. of Metals (London) (jointly), Cambridge, Mass. (H. M. Burte, Air Force Materials Lab. (LL), Wright-Patterson Air Force Base, Fairborn, Ohio 45433)

4–5. American Assoc. of **University Professors**, New Orleans, La. (B. H. Davis, AAUP, 1785 Massachusetts Ave., NW, Washington, D.C. 20036)

4–6. American Assoc. for **Cancer Research**, 63rd annual, Boston, Mass. (H. J. Creech, Inst. for Cancer Research, 7701 Burholme Ave., Philadelphia, Pa. 19111)

4–6. Midwestern **Psychological** Assoc., Cleveland, Ohio (Miss W. F. Hill, Dept. of Psychology, Northwestern Univ., Evanston, Ill. 60201)

4–7. **Biological Medicine**, 2nd intern. symp., Lausanne, Switzerland. (2e Symp. international de médecine biologique, Chemin du Frêne 11, CH-1004 Lausanne)

4–7. **Symbiosis in the Sea**, Georgetown, S.C. (W. B. Vernberg, Belle W. Baruch Research Inst., Univ. of South Carolina, Columbia 29208)

5. **Future Patterns in Health Care Delivery**, Professional Group on Engineering in Medicine and Biology, Philadelphia, Pa. (Miss H. Yoman, IEEE Office, Univ. of Pennsylvania, Philadelphia 19104)

5–6. Minnesota **Acad. of Science**, Marshall. (M. I. Harrigan, MAS, 3100 38th Ave., S., Minneapolis 55406)

5–6. North Dakota **Acad. of Science**, Dickinson. (B. G. Gustafson, Div. of Continuing Education, Univ. of North Dakota, Grand Forks 58201)

5–6. **Trace Elements in Our Environment**, Wisconsin Acad. of Sciences, Arts & Letters, Stevens Point. (J. R. Batt, 5001 University Ave., Madison, Wis. 53705)

6. American Soc. for **Clinical Nutrition**, Atlantic City, N.J. (C. E. Butterworth, Jr., Univ. of Alabama School of Medicine, Birmingham 35233)

6–11. American **Ceramic** Society, Inc., 74th annual, Washington, D.C. (F. P. Reid, ACS, 4055 N. High St., Columbus, Ohio 43214)

7–12. **Electronics** Div., Electrochemical Soc., Houston, Tex. (H. Huff, Texas Instruments Inc., P.O. Box 5936, M/S 144, Dallas 75222)

7–12. Society of **Photographic Scientists and Engineers**, 25th annual (includes repeat of seminar on Novel Audio-Visual Imaging Systems), San Francisco, Calif. (R. H. Wood, SPSE, 1330 Massachusetts Ave., NW, Washington, D.C. 20005)

8–10. American Soc. for **Quality Control**, Washington, D.C. (R. W. Shearman, ASQC, 161 W. Wisconsin Ave., Milwaukee, Wis. 53203)

8–11. **Quantum Electronics** Conf., American Inst. of Physics and Inst. of Electrical and Electronics Engineers, Montreal, P.Q., Canada. (Miss D. Edgar, Courtesy Associates, Suite 700, 1629 K St., NW, Washington, D.C. 20006)

8–12. Instrument Soc. of America, 13th natl. **chemical and petroleum instrumentation** symp., Philadelphia, Pa. (W. A. Bajek, UOP Process Div., 30 Algonquin Rd., Des Plains, Ill. 60016)

9. **Mycotoxins and Mycotoxicoses**, Symp., Univ. of Missouri, Columbia. (Office of Conferences and Short Courses, 103 Whitten Hall, Univ. of Missouri, Columbia 65201)

9–12. International Symp. on **Modeling Techniques in Water Resources**, Ottawa, Ont. Canada (A. B. Biswas, Water and Renewable Resources Sector, Dept. of Fisheries and Forestry, Ottawa)

10–12. **Federal Grants, Contracts, and Other Funding for Colleges, Universities, Hospitals, Nonprofit, and Other Institutions**, Washington, D.C. (Fifth Inst., Natl. Graduate Univ., 1630 Kalmia Rd., NW. Washington, D.C. 20012)

10–13. German **Röntgen** Soc., 53rd congr., Stuttgart. (F. Heuck, Zentral-Röntgeninstituts des Katharinenhospitals der Stadt Stuttgart, 7000 Stuttgart 1, Kriegsbergstr. 60)

10–13. Society of **Technical Writers and Publishers**, Boston, Mass. (C. T. Youngblood, Suite 421, 1010 Vermont Ave., NW, Washington, D.C. 20005)

11–13. **Radionuclide Carcinogenesis**, 12th symp., Richland, Wash. (Mrs. J. A. Harrison, Biology Dept., Battelle, Pacific Northwest Lab., Richland 99352)

11–13. Symposium on **X- and Gamma-ray Astronomy** (joint IAW/COSPAR), Madrid, Spain. (R. Giacconi, American Science and Engineering, Inc., 955 Massachusetts Ave., Cambridge, Mass. 02139)

14–18. **Radiation Research** Soc., 20th annual, Portland, Ore. (R. J. Burke, Jr., RRS, 4211 39th St., NW, Washington, D.C.

14–19. American **Radium** Soc., Boca Raton, Fla. (J. M. Vaeth, ARS, 1600 Divisadero St., San Francisco, Calif. 94115)

15–17. American Inst. of **Chemists**, Niagara Falls, N.Y. (P. B. Slawter, Jr., AIC, 79 Madison Ave., New York 10016)

15–18. Symposium on **Biochemistry of Gene Expression in Higher Organisms**, Intern. Union of Biochemistry, Sydney, Australia. (J. W. Lee, Australian Biochemical Soc., CSIRO Wheat Research Unit, Private Bag, P.O. North Ryde, New South Wales 2113)

15–19. American **Industrial Hygiene** Assoc., San Francisco, Calif. (E. L. Schall, AIHA, 210 Haddon Ave., Westmont, N.J. 08108)

15–19. Society of **Plastics Engineers**, Chicago, Ill. (C. C. Campbell, SPE, 656 W. Putnam Ave., Greenwich, Conn. 06830)

16–18. **Biting Flies and the Environment**, Edmonton, Alta., Canada. (S. McIver, Dept. of Parasitology, School of Hygiene, Univ. of Toronto, Toronto 181, Ont., Canada)

16–18. **Carbon and the Biosphere**, Brookhaven Symp. in Biology No. 24, Upton, N.Y. (G. M. Woodwell, Dept. of Biology, Brookhaven Natl. Lab., Upton 11973)

16–18. **Computer** Conf., American Federation of Information Processing Societies, Inc., Atlantic City, N.J. (T. C. White, AFIPS, 210 Summit Ave., Montvale, N.J. 07645)

17–19. **Drug Information** Assoc., New York, N.Y. (J. J. Harris, Galloping Hills Rd., Kenilworth, N.J. 07033)

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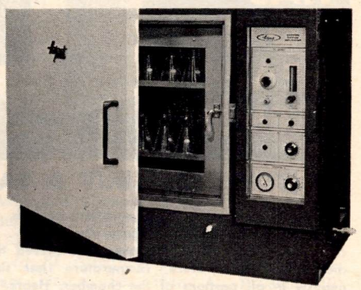

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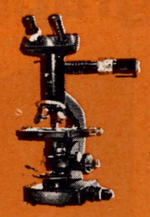

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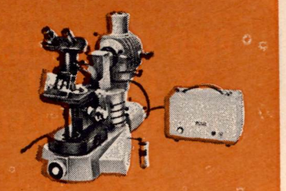

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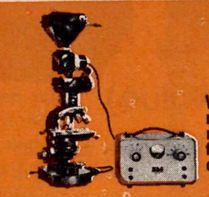

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Circle No. 30 on Readers' Service Card

18. Memorial Symp. on **Human Development and Reproductive Biology**, Washington, D.C. (L. V. Leak, Dept. of Anatomy, College of Medicine, Howard Univ., 540 W St., NW, Washington, D.C. 20001)

18–19. Southern **Textile Research** Conf., American Assoc. of Textile Chemists and Colorists, Hilton Head Island, S.C. (A. Giamara, 59 Route 10, East Hanover, N.J. 07936)

21–24. **Underground Transmission** Conf., 1st, Pittsburgh, Pa. (Inst. of Electrical and Electronics Engineers, Inc., 345 E. 47 St., New York 10017)

21–25. Institute of **Food Technologists**, Minneapolis, Minn. (C. L. Willey, IFT, 221 N. LaSalle St., Chicago, Ill. 60601)

22–24. **International Microwave** Symp., Inst. of Electrical and Electronics Engineers, Inc., Chicago, Ill. (P. P. Toulios, IIT Research Inst., 10 W. 35 St., Chicago 60616)

23–26. Society for **Experimental Stress Analysis**, Cleveland, Ohio. (B. E. Rossi, 21 Bridge Sq., Westport, Conn. 06880)

25–26. **Storage Polyglucosides**, New York Acad. of Sciences, New York, N.Y. (J. F. Frederick, Research Labs., Dodge Chemical Co., Bronx, N.Y. 10469)

25–27. **Mechanisms and Regulation of Craniofacial Morphogenesis**, Nymegen, The Netherlands. (F. Van der Linden, Dept. of Orthodontics, Univ. of Nymegen, "Heyendael," Philips van Leydenlaan 25, Nymegen)

28–2. National Conf. on **Social Welfare**, 99th, Chicago, Ill. (J. R. Hoffer, 22 W. Gay St., Columbus, Ohio 43215)

28–3. International College of **Surgeons**, 18th intern. biennial congr., Rome, Italy. (P. Stefanini, 1516 Lake Shore Dr., Chicago, Ill. 60610)

30–2. International Federation of Associations of **Textile Chemists and Colorists**, 9th congr., Munich, Germany. (Secretariat, 9th FATCC Congr., Rohrbacker Str. 76, D-6900 Heidelberg-1, Germany)

30–4. **Space Simulation**, Inst. of Environmental Sciences, New York, N.Y. (IES, 940 E. Northwest Highway, Mount Prospect, Ill. (60056)

31–2. **Endotoxin** Conf., Warrenton, Va. (EC, Channing Lab., Boston City Hospital, Boston, Mass. 02118)

31–2. American Inst. of **Industrial Engineers**, Anaheim, Calif. (J. F. Jericho, AIIE, 345 E. 47 St., New York 10017)

June

1–2. **Environmental and Water Resources Engineering** Conf., Nashville, Tenn. (E. L. Thackston, Dept. of Environmental and Water Resource Engineering, Vanderbilt Univ., Nashville 37203)

1–2. **Laboratory Animal Considerations in Toxicology and Related Disciplines**, East Brunswick, N.J. (W. H. Mitchell, P.O. Box 130, New Britain, Pa. 18901)

1–3. **Cancer Chemotherapy**, natl. conf., American Cancer Soc. and Natl. Cancer Inst., New York, N.Y. (S. L. Arje, ACS, 219 E. 42 St., New York 10017)

2. **Endotoxin** Conf., Warrenton, Va. (EC, Channing Lab., Boston City Hospital, Boston, Mass. 02118)

4–8. **Special Libraries** Assoc., Boston, Mass. (F. E. McKenna, SLA, 235 Park Ave. S., New York 10003)

4–8. **Tissue Culture** Assoc., Los Angeles, Calif. (R. H. Kahn, Dept. of Anatomy, Univ. of Michigan, Ann Arbor 48104)

4–9. **Mass Spectroscopy and Allied Topics**, American Soc. for Mass Spectrometry, Dallas, Tex. (F. E. Saalfeld, Naval Research Laboratory, Code 6110, Washington, D.C. 20390)

5–7. Natural **Gas Research and Technology**, 2nd conf., American Gas Assoc., Atlanta, Ga. (L. A. Sarkes, AGA, 1515 Wilson Blvd., Arlington, Va. 22209)

5–7. **Intestinal Microflora**, 2nd intern. symp., Columbia, Mo. (Conference Section, Continuing Medical Education, M-175 Medical Center, Columbia 65201)

5–7. American **Physical** Soc., Albuquerque, N.M. (W. W. Havens, Jr., APS, 335 E. 45 St., New York 10017)

5–8. **Coastal Mapping** Symp., American Soc. of Photogrammetry, Washington, D.C. (ASP, 105 N. Virginia Ave., Falls Church, Va. 22046)

5–8. United Nations Conf. on the **Human Environment**, Stockholm, Sweden. United Nations Headquarters, New York 10017)

5–9. **Pleasure, Reward, Preference**: Their Nature, Determinants, and Role in Behaviour, NATO-sponsored symp., Elsinore, Denmark. (D. E. Berlyne, Dept.

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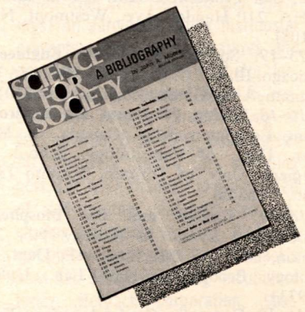

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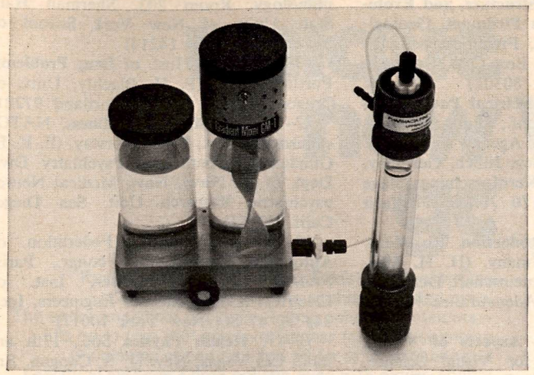

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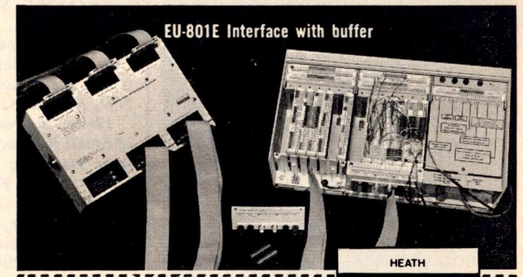

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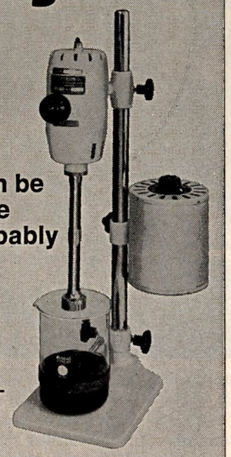

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of Psychology, Univ. of Toronto, Toronto 181, Ont., Canada)

5–9. **Stratigraphy, Structure, and Evolution of the Northern Piedmont**, Geological Soc. of America, Frederick, Md. (E. B. Eckel, GSA, P.O. Box 1719, Colorado Bldg., Boulder, Colo. 80302)

5–9. **Thermionic Electrical Power Generation**, 3rd intern. conf., jointly by European Nuclear Energy Agency and Intern. Atomic Energy Agency, Jülich, Germany. (P. von Handel, Kernforschungsanlage Jülich GmbH, D-5170 Jülich, Postfach 365, Germany)

6–10. **Animal Reproduction**, 7th intern. congr., Munich, Germany. (H. H. Messerschmidt, Arbeitsgemeinschaft, Deutscher Rinderzuchter, e V, Adenaurallee 176, 53 Bonn/Rh, Germany)

7–9. **Development Aspects of Vision**, 7th symp., Center for Visual Science, Rochester, N.Y. (J. L. Brown, CVS, University of Rochester, River Campus Sta., Rochester 14627)

7–10. American **Rheumatism** Assoc., Dallas, Tex. (Miss L. Bonfiglio, ARA, 1212 Avenue of the Americas, New York 10036)

8–9. **Cellular Modification and Genetic Transformation by Exogenous Nucleic Acids**, 6th Miles intern. symp., Baltimore, Md. (C. J. O'Donovan, Miles Labs., Inc., Elkhart, Ind. 46514)

8–10. International Assoc. for **Cereal Chemistry**, Vienna, Austria. (IACC, A-2320 Schwechat, Schmidgasse 3-7, Austria)

9–11. American Assoc. of **Neuropathologists**, Chicago, Ill. (E. P. Richardson, Jr., Neuropathology Lab., Massachusetts General Hospital, Boston 02114)

10–11. **Animal and Human Conditioning: Techniques and Theories in Drug Abuse Research**, Portland, Ore. (P. E. Blachly, Univ. of Oregon Medical School, Portland 97201)

11–15. **Medical Library** Assoc., Inc., San Diego–Coronado, Calif. (Mrs. H. B. Schmidt, MLA, 919 N. Michigan Ave., Chicago, Ill. 60611)

11–16. American Soc. of **Medical Technologists**, Minneapolis, Minn. (S. B. Friedheim, ASMT, Suite 1600, Hermann Professional Bldg., Houston, Tex. 77025)

12–14. **Computers in the Undergraduate Curricula**, Atlanta, Ga. (Southern Regional Education Board, 130 Sixth St., NW, Atlanta, Ga. 30313)

12–14. **Improvement of the Capabilities of Small Research and Development Firms in a Declining R&D Environment**, National Science Foundation/Small Business Administration Conf., Washington, D.C. (J. D. Johnson, Center for the Study of Private Enterprise, American Univ., Washington, D.C. 20016)

12–14. Society for **Industrial and Applied Mathematics**, 20th, Philadelphia, Pa. (H. B. Hair, SIAM, 33 S. 17 St., Philadelphia 19103)

12–14. American **Neurological** Assoc., 97th annual, Chicago, Ill. (S. A. Trufant, Cincinnati General Hospital, Cincinnati, Ohio 45229)

12–15. American Assoc. for the **Advancement of Science**, Pacific Div., Eugene, Ore. (R. C. Miller, California Acad. of Sciences, Golden Gate Park, San Francisco 94118)

12–15. **Immunology**, 3rd intern. conf., Buffalo, N.Y. (N. R. Rose, Center for Immunology, Room 203, Sherman Hall, State Univ. of New York School of Medicine, Buffalo 14214)

12–16. Western Inst. of **Drug Problems**, Portland, Ore. (P. H. Blachly, Univ. of Oregon Medical School, Portland 97201)

12–16. **Life Stress and Illness**, NATO-sponsored symp., Beito, Norway. (E. K. E. Gunderson, Operational Psychiatry Div., Dept. of the Navy, Navy Medical Neuropsychiatric Research Unit, San Diego, Calif. 92152)

12–17. International Federation of **Automatic Control**, 5th congr., Paris, France. (Meetings Officer, Inst. of Electrical and Electronics Engineers, Inc., 345 E. 47 St., New York 10017)

12–17. **Health Physics** Soc., 17th annual, Las Vegas, Nev. (J. S. Coogan, Environmental Protection Agency, Western Environmental Research Lab., P.O. Box 15027, Las Vegas 89114)

12–17. **Pollution: Engineering and Scientific Solutions**, 1st intern. conf., Soc. of Engineering Science (cosponsored by Environmental Protection Agency, National Oceanic Atmospheric Administration, and Washington Univ.) Tel-Aviv, Israel. (E. Y. Rodin, Dept. of Applied Mathematics, Washington Univ., St. Louis, Mo. 63130)

13–16. Canadian Federation of **Biological** Societies jointly with Canadian Soc. of **Microbiologists**, Quebec, P.Q., Canada. (D. T. Armstrong, Dept. of Physiology, Univ. of Western Ontario, London 72, Ont., Canada)

13–16. **Simulation** Conf., San Diego, Calif. (M. K. Horn, Cities Service Oil Co., P.O. Box 50408, Tulsa, Okla. 74150)

14–16. International Symp. on **Metabolism and Membrane Permeability of Erythrocytes, Thrombocytes, and Leucocytes**, Vienna, Austria. (K. Moser, Wiener Medizinische Akademie, Alserstrasse 4, 1090 Vienna)

14–17. American **Medical Women's** Assoc., Seattle, Wash. (Mrs. G. F. Conroy, AMWA, 1740 Broadway, New York 10019)

14–18. American Assoc. of **Bioanalysts** and California Assoc. of Bioanalysts (joint), Scottsdale, Ariz. (D. Birenbaum, AAB, 411 N. 7 St., St. Louis, Mo. 63101)

18–19. Soc. of **Wood Science and Technology**, Dallas, Tex. (E. L. Schoffer, SWST, P.O. Box 5062, Madison, Wis. 53705)

18–21. American **Dairy Science** Assoc., Blacksburg, Va. (C. Cruse, ADSA, 113 N. Neil St., Champaign, Ill. 61820)

18–22. International Congr. on **Lipids**, Göteborg, Sweden. (R. Marcuse, Intern. Soc. for Fat Research, Lipidforum, c/o SIK, FACK, S-400 21 Göteborg 16)

18–22. Association of **Food and Drug Officials**, 76th annual, Monticello, N.Y. (K. A. Silver, Room 700, 850 Third Ave., Brooklyn, N.Y. 11232)

18–22. American **Medical** Assoc., San Francisco, Calif. (L. W. Prang, Records Section, AMA, 535 N. Dearborn St., Chicago, Ill. 60610)

18–22. American **Nuclear** Soc., Las Vegas, Nev. (H. Coffer, CER Geonuclear Corp., P.O. Box 15090, Las Vegas 89114)

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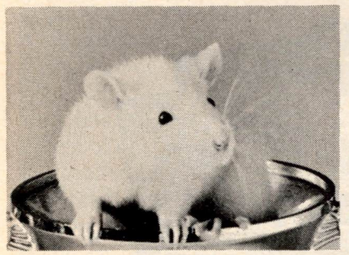

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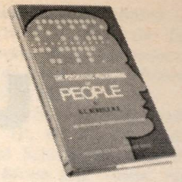

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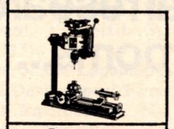

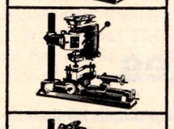

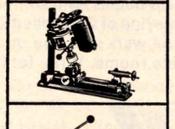

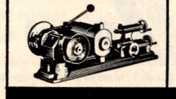

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18–23. International Congr. of **Endocrinology**, 4th, Intern. Soc. of Endocrinology, Washington, D.C. (G. D. Aurbach, Section on Mineral Metabolism, Natl. Inst. of Health, Bethesda, Md. 20014)

18–24. **Water Pollution** Research, 6th intern. conf., Jerusalem, Israel. (Organizing Committee, 6th Intern. Conf. on Water Pollution Research, P.O. Box 16271, Tel Aviv, Israel)

19–21. **Colloid** Symp., 46th natl., Div. of Colloid and Surface Chemistry, American Chemical Soc., Amherst, Mass. (R. L. Rowell, Dept. of Chemistry, Univ. of Massachusetts, Amherst 01002)

19–21. American College of **Preventive Medicine**, San Francisco, Calif. (W. Bentley, 801 Old Lancaster Rd., Bryn Mawr, Pa. 19010)

19–21. **Surface Properties and Surface States of Electronic Materials**, Rolla, Mo. (W. J. James, Graduate Center for Materials Research, Space Sciences Research Center, Univ. of Missouri, Rolla 65401)

19–21. **Watersheds in Transition**, American Water Resources Assoc., Fort Collins, Colo. (T. G. McLaughlin, Water Resources Div., U.S. Geological Survey, Denver, Colo.)

19–22. **Air Pollution Control** Assoc., 65th annual, Miami Beach, Fla. (Public Relations Dept., APCA, 4400 Fifth Ave., Pittsburgh, Pa. 15213)

19–22. American Soc. for **Engineering Education**, Lubbock, Tex. (L. B. Williams, ASEE, Suite 400, 1 Dupont Circle, Washington, D.C. 20036)

19–22. American **Vacuum** Soc., Pittsburgh, Pa. (AVS, 335 E. 45 St., New York 10017)

19–23. **Influence of Culture on Ergonomics**, Oosterbeck, The Netherlands. (A. Chapanis, Dept. of Psychology, Johns Hopkins Univ., Baltimore, Md. 21218)

21–23. **Experimental Medicine and Surgery in Primates**, 3rd conf., Lyon, France. (J. Moor-Jankowski, LEMSIP, New York Univ. Medical Center, 500 First Ave., New York 10016)

21–23. **Plastics in Packaging**, Pullman, Wash. (R. A. V. Raff, Research Div., College of Engineering, Washington State Univ., Pullman 99163)

21–23. **Role and Value of Measurement** (jointly sponsored by American Soc. for Quality Control, Inst. for Electrical and Electronics Engineers, Instrument Soc. of America, Natl. Bureau of Standards, Natl. Conf. of Standards Labs., and Precision Measurements Assoc.), Boulder, Colo. (G. Goulette, 130 Academy Bldg., Univ. of Colorado, Boulder 80302)

22–23. **Legal Aspects of Computerized Information Systems**, intern. symp., Federal Council of Science and Technology, Washington, D.C. (J. H. Farmakides, Office of Science Information Services, COSATI, National Science Foundation, Washington, D.C. 20550)

22–24. American Assoc. of **Physics Teachers**, Albany, N.Y. (W. F. Johnson, AAPT, 1785 Massachusetts Ave., NW, Washington, D.C. 20036)

22–25. **Optical Manufacturers** Assoc., St. Louis, Mo. (Albert A. Kohler Co., Inc., 15 Wilmot Lane, Riverside, Conn. 06878)

22–28. **Coordination Chemistry**, 14th intern. conf. (sponsored by National Research Council of Canada and Chemical Inst. of Canada), Toronto, Ont., Canada. (C. J. L. Lock, Inst. for Materials Research, McMaster Univ., Hamilton, Ont.)

24–25. American **Diabetes** Assoc., Washington, D.C. (J. R. Connelly, ADA, 18 E. 48 St., New York 10017)

25–30. National **Education** Assoc., Atlantic City, N.J. (S. M. Lambert, NEA, 1201 16th St., Washington, D.C. 20036)

25–30. American Soc. for **Testing Materials**, 75th annual, Los Angeles, Calif. (H. H. Hamilton, ASTM, 1916 Race St., Philadelphia, Pa. 19103)

25–1. American **Library** Assoc., Chicago, Ill. (C. J. Hoy, ALA, 50 E. Huron St., Chicago, Ill.)

26–28. Institute of **Navigation**, West Point, N.Y. (R. E. Freeman, IN, Suite 832, 815 15th St., NW, Washington, D.C. 20005)

26–29. **Law of the Sea: Needs and Interests of Developing Countries**, 7th annual conf., Kingston, R.I. (Law of the Sea Inst., Univ. of Rhode Island, Kingston 02881)

26–29. American Assoc. of **Physicists in Medicine**, Philadelphia, Pa. (B. M. Galkin, Stein Research Center, 920 Chancellor St., Philadelphia 19107)

26–29. Society for the **Study of Reproduction**, 5th annual, East Lansing, Mich. (J. M. Yochim, Dept. of Physiology and Cell Biology, Univ. of Kansas, Lawrence 66044)

26–29. **Weather Modification**, 3rd conf., American Meteorological Soc., Rapid City, S.D. (R. A. Schleusener, Inst. of Atmospheric Sciences, South Dakota School of Mines and Technology, Rapid City 57701)

26–2. **Radiation** Commission, Intern. Assoc. of Meteorology and Atmospheric Physics, intern. symp., Sendai, Japan. (J. London, Univ. of Colorado, Boulder 80302)

27–30. Cheiron: The International Soc. for the **Behavioral and Social Sciences**, Calgary, Alta., Canada. (R. G. Weyant, Dept. of Psychology, Univ. of Calgary, Calgary 44)

27–30. International Study Group for **Research in Cardiac Metabolism**, 5th annual, Winnipeg, Man., Canada. (N. S. Dhalla, Dept. of Physiology, Faculty of Medicine, Univ. of Manitoba, Winnipeg 3)

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2–7. **Environment**, 36th annual conf., Natl. Environmental Health Assoc., New York, N.Y. (N. Pohlit, NEHA, 1600 Pennsylvania Ave., Denver, Colo. 80203)

5–8. **Shock Tube** Symp., 8th intern., London, England. (Symp. Secretary, Dept. of Aeronautics, Imperial College, Prince Consort Rd., London, S.W. 7)

6–8. **RF Plasma Heating**, American Physical Soc., Lubbock Tex. (M. O. Hagler, Dept. of Electrical Engineering, Texas Tech Univ., Lubbock 79409)

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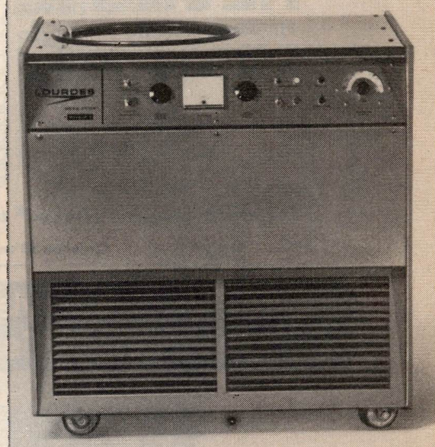

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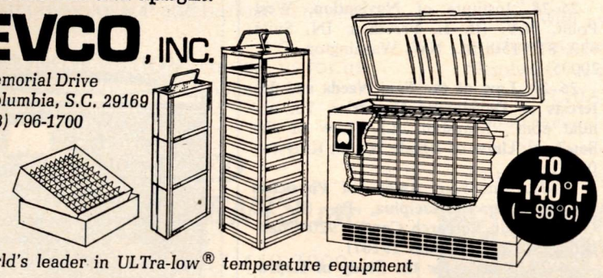

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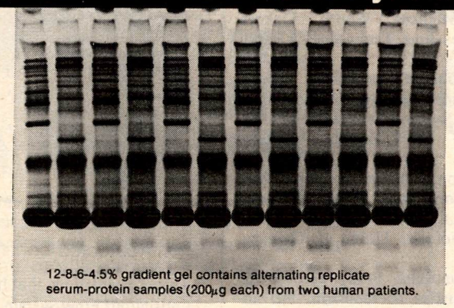

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9–12. **Molecular Beams**, 4th intern. symp., Cannes, France. (F. M. Devienne, Laboratoire de Physique Moléculaire des Hautes Energies, B.P.2 (06), Peymeinade, France)

9–14. American **Malacological** Union, Galveston, Tex. (A. S. Merrill, Biological Lab., Natl. Marine Fisheries Service, Oxford, Md. 21654)

9–14. **Power Engineering** Soc., San Francisco, Calif. (Meetings Officer, Inst. of Electrical and Electronics Engineers, Inc., 345 E. 47 St., New York 10017)

10–12. **DNA Synthesis in vitro**, 2nd annual Steenbock symp., Madison, Wis. (Mrs. M. Parker, Dept. of Biochemistry, 420 Henry Mall, Univ. of Wisconsin, Madison 53706)

10–14. **Interaction of Radioactive Contaminants with the Constitutents of the Marine Envronment**, Seattle, Wash. (J. H. Kane, Div. of Technical Information, U.S. Atomic Energy Commission, Washington, D.C. 20545)

10–14. **Rarefied Gas Dynamics**, 8th intern. symp., Stanford, Calif. (K. Karamcheti, Dept. of Aeronautics and Astronautics, Stanford Univ., Stanford 94305)

11–15. National Soc. of **Professional Engineers**, Denver, Colo. (P. H. Robbins, NSPE, 2029 K St., NW, Washington, D.C. 20006)

16–20. American **Veterinary Medical** Assoc., New Orleans, La. (M. R. Clarkson, AVMZ, 600 S. Michigan Ave., Chicago, Ill. 60605)

16–28. **Technology and the People**, Inst. on Man and Science, Rensselaerville, N.Y. (G. A. Enk, IMS, Rensselaerville 12147)

17–21. **Electron Probe Analysis** Soc. of America, 7th natl. conf., San Francisco, Calif. (C. G. Cleaver, General Electric Co., Vallecitos Nuclear Center, Bldg. 105, Pleasanton, Calif. 94566)

18–21. **Cyclotron** Conf., 6th intern., Vancouver, B.C., Canada. (N. Brearley, Univ. of British Columbia, Vancouver 8)

18–21. **Hormones, the Brain, and Behavior**, 3rd intern. symp., Intern. Soc. of Psychoneuroendocrinology, London, England. (R. P. Michael, Inst. of Psychiatry, De Crespigny Park, Denmark Hill, London SE5 8AF)

19–21. **Defects in Semiconductors**, intern. conf., Reading, England. (Meetings Officer, Inst. of Physics, 47 Belgrave Sq., London S.W.1, England)

19–22. **Calorimetry** Conf., 27th, Park City, Utah. (J. M. Sturtevant, Dept. of Chemistry, Yale Univ., New Haven, Conn. 06520)

23–28. **Illuminating Engineering** Soc., Tulsa, Okla. (P. C. Ringgold, IES, 345 E. 47 St., New York 10017)

24–30. **Angiology**, 8th intern. congr., Rio de Janeiro, Brazil. (D. F. M. Bunce, Dept. of Physiology, College of Osteopathic Medicine and Surgery, Sixth at Center, Des Moines, Iowa 50309)

26–31. Inter-American Meeting of **Neuroradiology**, Rio de Janeiro, Brazil. (A. Tomax Rezende, Caixa Postal 9031, ZC-02, Rio de Janeiro, Gb)

27–29. **Intracranial Pressure**, 1st intern. symp., Hannover, Germany. (M. Brock, Neurochirurgische Klinik, Medizinische Hochschule Hannover, 3 Hannover-Kleefeld, Roderbruchstrasse 101, Germany)

NEW ZEALAND SENIOR AND POSTDOCTORAL RESEARCH FELLOWSHIPS

The New Zealand National Research Advisory Council invites applications for 10 Senior and Postdoctoral Fellowships to be taken up in New Zealand in 1973. The awards will be for scientific research in Government Departments. A good working knowledge of English is required. There is no restriction regarding nationality of applicants, but successful candidates must meet the requirements of the New Zealand immigration authorities.

A grant equivalent to return economy class air fares from the Fellow's home to the New Zealand institution will be made. While in New Zealand reasonable travelling expenses incurred in connection with the research work will be paid.

If reciprocal social security between the Fellow's country and New Zealand does not apply, a medical insurance premium will be paid.

All emoluments are taxable. NZ$1 is approximately 47p sterling or US$1.19.

Senior Research Fellowships—Applicants should possess a Ph.D. degree or higher or have a distinguished record of scientific research. The fellowships are intended for research workers who have had several years professional experience and have published original material. Fellowships are normally for a period of from nine months to a year. If a Fellow's wife accompanies him a grant equivalent to her return fares will be paid provided the fellowship is for a term of at least nine months. If applicable, the employer's contribution to a superannuation scheme will be paid. The emoluments will range from NZ$8126 to NZ$12151 a year.

Postdoctoral Research Fellowships—Applicants should possess a Ph.D. or equivalent degree. The fellowships are intended for research workers who are recent graduates and may have had some research experience since graduation. Fellowships are normally for a period of from two to three years. If a Fellow's wife and family accompany him a grant equivalent to their return fares will be paid. A grant will also be made towards the cost of transport of personal effects. The emolument will be NZ$6791 a year.

Application forms and further particulars may be obtained from: **the Secretary, National Research Advisory Council, P.O. Box 8004, Wellington, NEW ZEALAND; The N.Z. Scientific Liaison Office, C.S.C., Africa House, Kingsway, London W.C.2, England, from the N.Z. Embassy, 19 Observatory Circle, N.W., Washington, D.C. 20008, U.S.A., from the Office of the High Commissioner for New Zealand, Suite 804, Commonwealth Buildings, 77 Metcalfe Street, Ottawa, Ontario, Canada, from the Office of the High Commissioner for New Zealand, P.O. Box 820, Canberra 2601, A.C.T., Australia, from the N.Z. Embassy, 26 Sanbancho Chiyoda-ku, Tokyo 102, Japan, from the New Zealand Embassy in Bonn, Djakarta, Paris, Rome, The Hague, Bangkok, Saigon, and from the Office of the High Commissioner for New Zealand in Sydney, Athens, New Delhi, Kuala Lumpur, Singapore, San Francisco, and Los Angeles.**

Applications must reach the Council Secretary **by 30 September 1972.**

Personnel Placement

POSITIONS WANTED

Biologist/Physiologist, Ph.D. desires academic position. Background in teaching (undergraduate, graduate, professional), research and administration. Box 180, SCIENCE. X

Cell Biologist, Ph.D. Several years' teaching experience on college level. Seeks teaching/research or research position. Research interests —human and animal cytogenetics, effects of physical and chemical agents on chromosomes, meiosis, chromosome structure. No geographical preference. Box 181, SCIENCE. X

Chemist, Ph.D. 1967; 4 years' postdoctoral interpretation of mass spectre of natural products, isotope labeling, organometallics. Seeks position in natural products, bioorganic or environmental chemistry. Box 182, SCIENCE. X

Chemist-Crystallographer, Ph.D. 1960. Six years in research institution. Purification, crystallization of enzymes for x-ray crystallography. Five years of university teaching. Publications. Seeking academic, research, or industrial position. Box 183, SCIENCE. X

Clinical Chemistry postdoctoral fellowship wanted by physiologist, Ph.D., age 28. Training in tracer techniques; publications; teaching experience. Box 184, SCIENCE. X

Microbiologist, Ph.D., unlicensed M.D., experience and publications. Clinical laboratory or research. Box 185, SCIENCE. X

Ph.D., Pharmacology/Basic Science background. Medical teaching experience. Prefer academic/research/paramedical position. Available September. Box 186, SCIENCE. X

Physicist, Ph.D., desires academic or research or other challenging position; 2 years of college teaching, 2 years of programming in PL/1 and FORTRAN in biomedical, biostatistical research. Write P.O. Box 194, Peirmont, N.Y. 10968.

Physiologist, Ph.D., 31, desires college-level teaching position. Teaching and postdoctoral experience, publications. Available summer 1972. Box 187, SCIENCE. X

Physiologist, Ph.D. Experienced in all areas of physiology and biological sciences. Numerous publications. Box 164, SCIENCE. X

Psychologist, Ph.D., 31, department chairman, 5 years' teaching experience, 17 publications in experimental area. Prefers research job, but (almost) anything else considered. Box 188, SCIENCE. X

Planetarium Director, age 33, 12 years' teaching experience including all levels, K-12, college undergraduate and graduate, NSF-funded science program; astronomy, biology, earth science, physical science, chemistry, meteorology, aerospace; conducted research in auroras and atmospheric phenomena; seeks challenging position on the East Coast. Box 189, SCIENCE. X

Teacher and Researcher; Ph.D.; experience in geology, biology, and environmental sciences; seeks faculty or administrative position; National Academy of Sciences scientist; available September 1972. Box 190, SCIENCE. X

Toxicologist/Physiologist, Ph.D. December 1971, M.S. Occupational and environmental health, teaching and research experience. Desires academic or industrial position in toxicology-environmental sciences. Box 191, SCIENCE. X

Toxicologist, Ph.D., 11 years' experience including forensic and pharmacological research and teaching (8 years), seeks academic, research or forensic related position. Box 192, SCIENCE. X

Virologist, Ph.D. 20 years' experience. Major contributions in antivirals and viral diagnosis. Over 60 publications. Industrial, clinical, academic, and administrative experience. Seeks responsible position. Opportunity for spouse to attend graduate school. Box 193, SCIENCE. X

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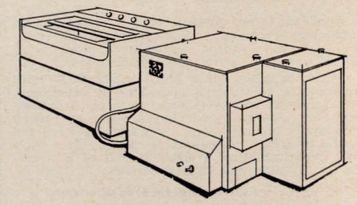

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Please Send Curriculum Vitae To:

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Naval Biomedical Research Laboratory
Naval Supply Center
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Phone: 415-832-5217

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Minimum salary for a Ph.D. is $12,000.00 with appropriate adjustments according to experience. The appointee will be required to teach in French. However, candidates who do not master French may apply provided they are willing to learn the language within a reasonable period. The Biology Department has a teaching staff of 20 members and some postdoctoral fellows.

Apply to: **Dr Lucien HUOT, directeur**
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Applications, by letter (three copies) together with a curriculum vitae and the names of two referees, should be sent to the **Secretary to the University, Old College, South Bridge, Edinburgh, EH8 9YL, Scotland,** from whom further particulars may also be obtained. Applications should be sent as soon as possible, quoting reference 1024.

CANDIDATURES DEMANDEES AU POSTE DE DIRECTEUR D'UN DEPARTEMENT DES SCIENCES BIOLOGIQUES

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POSTDOCTORAL POSITION IN NEUROPHYSIOLOGY

Position available for Ph.D. in Physics, Chemistry, Engineering, or Biology in laboratory currently studying neurophysiology and biophysics of photoreceptors. Applicants should provide curriculum vitae and list of references. Please send inquiries to:

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Send application, vitae, and the names of three referees to **Dr. Kenneth Bell, University of Pittsburgh at Greensburg, 122 North Maple, Greensburg, Pa. 15601.**

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Dr. Warren P. Porter
Department of Zoology
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COURSES

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The Santa Catalina Marine Biological Laboratory is pleased to announce its SUMMER AND FALL PROGRAMS FOR 1972:

June 21-July 25: BASIC NEURONAL PROCESSES (ELECTRO-BIOLOGY)
July 27-August 30: BEHAVIOR OF MARINE ANIMALS
September 6-September 26: OIL POLLUTION AND THE MARINE ENVIRONMENT
October 2-November 4: COMPARATIVE PHYSIOLOGY OF MARINE ANIMALS and ADVANCED UNDERWATER TECHNIQUES
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January 3-February 6 (1973): MARINE ECOLOGY

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For additional information, write to **Dr. Russel L. Zimmer, Director, Santa Catalina Marine Biological Laboratory, P.O. Box 398, Avalon, California 90704 or telephone area code 213, Avalon 811** (operator's assistance is required).

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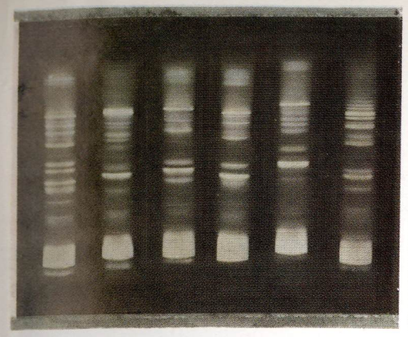

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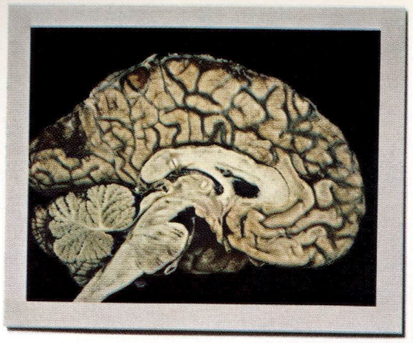

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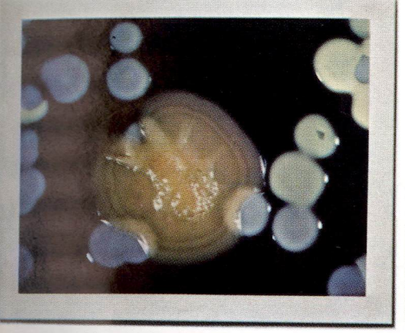
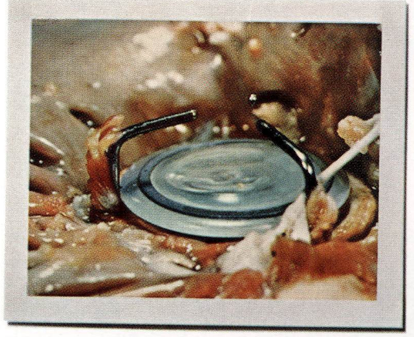
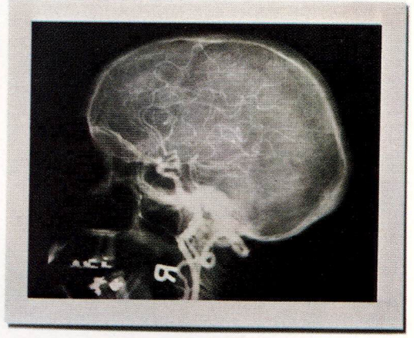
Photomicrograph, human leukemia (1600 X).



Macrophotograph, blood culture.



Artificial valve in animal heart.



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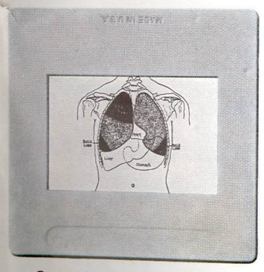

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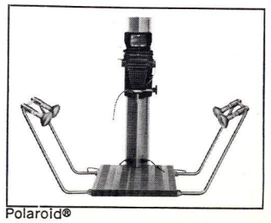

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April 19, 1972

NOTES ON MODELING

Known factors and relationships in a system are put in mathematical terms and combined into a mathematical model that will act like the system described by the statements. The closer the statements describe the real system the closer the model results will be to the system.

The process of a model can be calculated by hand, but a modern, high speed computer allows fast processing of complex models and therefore makes it possible to try models with many different assumptions.

Mentally we can predict the results of very simple models but as they become slightly complex the results are often anti-intuitive.

Models have several uses. First it makes a good format for presenting ideas because the assumptions are presented in algorithmic form and the expected results are clearly stated. Fragments of the model then can be stated as equations.

Secondly, models are learning tools that make us wiser in making decisions. Models can develop insights into the system one is responsible for making decisions for, ibid., business or economy or weapons systems.

Thirdly, with great care and careful cognizance a model can be used to help predict the future. Animal populations have fluctuated as the food supplies have saturated and recovered. In the same way, models of human life in the world have been made t o show violent fluctuations that could happen to the human race. These have been demonstrated by Forrester and Meadows. Although models have been used

EXPLICIT MATHEMATICAL MODELS OF SOCIAL SYSTEMS

A year ago, in a book entitled, "World Dynamics", J. W. Forrester presented an explicit model of the world which projected the future of population and resources. This year, a more detailed model was published in a book entitled, "The Limits of Growth", written by a team headed by Dennis L. Meadows. The models created were received with great enthusiasm by some and with most severe criticism by many others.

Many appreciated the work because it was in explicit terms. It presented the predicament they felt the world was getting into in terms that could be readily discussed and in a way that the problems had to be faced. By others, the model was soundly criticized because people did not agree with the assumptions that made up the model or because they felt the showmanship with which the books were presented created undue ~~interest~~ faith in ~~the problem, or~~ at least in this particular model.

A model is a useful vehicle for presenting and discussing an idea. When arguing for or against a model, one has to explicitly present his assumptions and show how he arrived at the conclusions.

Secondly, a model is also a learning tool. Even if the model is far from perfect, we can learn about the model by changing assumptions and seeing what happens.

Thirdly, used with great care and caution, a model can help predict the future because the results of a model are explicit. It has been assumed that Forrester and Meadows were explicitly predicting the future. In the preface of his book, Forrester says:

> "But all models will be tentative, for new insights will continue to appear. Because a truly final model of the world system is unlikely ever to be achieved, and because of the widespread interest that has already been expressed in this effort, it seems appropriate to present the existing assumptions and implications in this book."

Forrester goes on to say:

"Man acts at all times on the models he has available. Mental images are models. We are now using those mental models as a basis for action. Anyone who proposes a policy, law, or course of action is doing so on the basis of the model in which he, at that time, has the greatest confidence."

"It is to be hoped that those who believe they already have some different model that is more valid will present it in the same explicit detail, so that its assumptions and consequences can be examined and compared. To reject this model because of its shortcomings without offering concrete and tangible alternatives would be equivalent to asking that time be stopped. But the world will continue to turn. We always use the most acceptable model at any point in time. But how should we proceed so that the most acceptable model is also the best one that is available? We should try for three things. First, the best existing model should be identified at each point in time. Second, the best currently existing model should be used in preference to traditional models that may be less clear and less correct. Third, aggressive effort should be devoted to a continual improvement in the available models of the world system."

"It seems traditional for explicit models of social systems to be greeted by vague criticisms about their lack of perfection. Instead, we need equally explicit alternatives with a demonstration that the alternative leads to a different and more plausible set of conclusions. By proposal and counter proposition our understanding of social systems can advance."

Kenneth H. Olsen
April 1972

DRAFT:DGLuenberger:ba 3-16-72

MEMORANDUM FOR

THE PRESIDENT

SUBJECT: My views concerning the recent book The Limits to Growth by Donella H. Meadows, Dennis L. Meadows, Jorgen Randers, William W. Behrens III.

The Club of Rome, an informal group of industrialists, scientists, and economists, from many countries, founded by Aurelio Peccei, has initiated a Project on the Predicament of Mankind. The first phase of their project has culminated in the publication of the book The Limits to Growth which represents the product of an 18-month study at MIT led by Dennis Meadows. The study attempts to model the interactions between global levels of population, capital, food, nonrenewable resources, and pollution; and to project, with the aid of a computer, these levels into the future in order to glimpse, at least in aggregate form, the future world situation. It concludes that if we continue on what is apparently our current path, the world will suffer a major crisis sometime within fifty to one hundred years, and moreover, that a prompt change in global policies in order to restrict economic growth and population increase is essential to forestall such a crisis.

Studies of this type have been made before -- one of the most renowned being Harrison Brown's The Next Hundred Years (1957).

They can be important indicators of potential hazards in directions implied by present policies. It is appropriate to continuously update our projections and to improve our forecasting methodology by, for instance, employing computers to manipulate data and to test hypothetical models. This new study, however, falls far short of meeting today's standards of scientific inquiry in this area. The model's structure does not reflect existing economic theory, and several specific assumptions are highly suspect or counter to historical evidence. For example, the model assigns limits to the technological advances achievable in the areas of pollution control and material recycling. The model assumes that birth rate is inextricably linked to average income even through decades of transition from affluence to starvation. The study does not account for the price increases certain to accompany shortage of basic materials, nor for the eventual substitution of abundant but currently costly materials (e.g. aluminum) for other materials that may become scarce (e.g. steel). The model does not address the possible substitution of service consumption for capital consumption. And its assumptions relating to the possible discovery of new reserves of raw materials is more conservative than history would imply. In essence, the model restricts the variables that might alleviate

disaster -- recycling, population control, and technological advance -- to remain fixed, or at best to change by finite increments, but allows the variables associated with disaster -- pollution, population, resource consumption, etc. -- to grow exponentially, without bound. The resulting world crisis follows directly from these assumptions.

Grave hazards do face the world if our current rate of growth continues unchecked. The world and its resources are but finite and obviously cannot sustain indefinite growth. The Limits to Growth reaffirms that message, and suggests, without offering a workable plan of its own, that we must begin to think about such problems.

We are already attacking these problems on a number of fronts. The President's Commission on Population Growth and the American Future is examining the population question and its preview report last weekend suggested that we seek a decrease in population growth. The United States is an active participant in the U. N. Conference on the Human Environment to take place in Stockholm in June 1972. There, environmental problems will be dealt with on a worldwide basis for the first time. Last year in the President's Energy Message a new commitment to the development of low-cost nuclear energy sources was made. Availability of

abundant energy would allow increased recycling of materials and greater access to materials now too costly to produce. We have initiated a major attack on pollution, a problem just recently recognized as serious, through, for example, the establishment of the Environmental Protection Agency.

By suggesting that we should immediately strive to attain a stable equilibrium, the book invites the question as to the detailed form of that equilibrium. At a symposium held at the Smithsonian on March 2 to discuss this book, Ambassador L. K. Jha of India questioned whether an equilibrium might be accompanied by severe inequality among nations. A model dealing with aggregated world variables, such as the Meadows' model, cannot provide insight into that question, but it has been suggested that we should seek equilibrium through the establishment of world central planning institutions. We do not have, however, a substantial basis on which to define the role of such an institution.

Without question there is room for responsible work in this field, for we must constantly strive to illuminate the future implications of present policies. Computer models can be of invaluable help. A model might be sectorized with developed and undeveloped regions. It might incorporate a price system for goods and services.

It should account for major technological advances in areas such as telecommunications that certainly will affect the pattern of world growth. But such models should be subjected to careful scrutiny by experts in the scientific community and their limitations and assumptions made clear before the graphs of a few particular cases are displayed as predictions of the future.

Edward E. David, Jr.
Science Adviser

COSPUP Meeting

Sunday, April 23 -- Room 150, 2101 Constitution Avenue, NW.

10:00 - 10:45	Discussion of report, Limits of Growth. The Drs. Meadow will give a slide presentation and tell what they think the book says.
10:45 - 11:30	Discussion of Is There An Optimum Level of Population? Prof. S. Fred Singer, Professor of Environmental Sciences, University of Virginia. [Singer is a critic of both the Meadows and Forrester books.]
11:30 - 12:30	General discussion of issues raised by earlier presentations
12:30 - 1:30	Lunch
1:30 - 2:15	To Live on Earth: Man and His Environment in Perspective, a presentation by Sterling Brubaker of Resources for the Future, Inc. (related to the other two books)
2:15 - 2:45	Resources for the Future input to the Commission on Population Growth and the American Future - Hans Landsberg
2:45 - 4:00	General discussion of issues raised during afternoon session and how they relate to issues developed during morning session. [The Drs. Meadows and Prof. Singer will be present for this discussion.]
4:00	Executive Session

Monday, April 24 -- Room 280, 2101 Constitution Avenue, NW.

9:30 - 10:15	Population and The American Future, Robert Parke, Jr., Deputy Director of Population Growth and The American Future.
10:15 - 11:15	General discussion
11:15 - 12:15	Committee business -- Survey of Materials Science and Engineering - Morris Cohn, MIT

Invitees: Members of the Academy: Roger Ravelle, James Neill, Harrison Brown (will be in and out), George Kistiakowsky (in and out), and Preston Cloud. Someone from Potomac Associates, publisher of the Meadows book may come, though this is not certain.

DRAFT:DGLuenberger:ba 4-18-72

MEMORANDUM FOR

THE PRESIDENT

SUBJECT: My views concerning the recent book The Limits to Growth by Donella H. Meadows, Dennis L. Meadows, Jorgen Randers, William W. Behrens III.

The Club of Rome, an informal group of industrialists, scientists, and economists, from many countries, founded by Aurelio Peccei, has initiated a Project on the Predicament of Mankind. The first phase of their project has culminated in the publication of the book The Limits to Growth which represents the product of an 18-month study at MIT led by Dennis Meadows, whose work derives from Jay Forrester. The study attempts to model the interactions among global levels of population, capital, food, nonrenewable resources, and pollution, viz., to project, with the aid of a computer, these levels into the future. Each variable is treated in aggregate form for the total planet. The study concludes that if current trends continue without conscious intervention, the world will suffer a major crisis (defined as a relatively abrupt decline in global population) sometime within fifty to one hundred years. The authors suggest that a prompt change in global policies in order to restrict economic growth and population increase is essential to forestall such a crisis.

The specific results of the study cannot be considered reliable. The model's structure does not reflect existing economic theory or the prospects for new technologies. Several specific assumptions are highly suspect or counter to historical evidence: The model (a) assigns limits to the technological advances achievable in the areas of pollution control and material recycling; (b) assumes that birth rate is inextricably linked to average income even through decades of transition from affluence to starvation; (c) ignores the consequences of the price increases certain to accompany shortage of basic materials; (d) ignores the eventual substitution of abundant but currently costly materials (e. g. aluminum) for other materials that may become scarce (e. g. steel); (e) ignores, in the sense of projected timing, significant finds of nonrenewable resources and expansion of the effective size of those reserves by use of new extraction technologies; and (f) fails to address the possible substitution of service consumption for capital consumption. In essence, the model restricts significant improvement in future prospects for those variables that might postpone disaster, but allows the variables associated with disaster -- pollution, population, resource consumption, etc. -- to continue to grow exponentially. The projected world crisis follows directly from these assumptions.

Grave hazards do face the world if our currrnt rate of growth continues unchecked. The world and its resources are but finite and obviously cannot sustain indefinite growth. The Limits to Growth reaffirms that message, and suggests, without offering a workable plan of its own, that there is relatively little time in which to think seriously about such problems if conscious, large-scale intervention does indeed prove to be the course of wisdom.

We are already attacking these problems on a number of fronts. The President's Commission on Population Growth and the American Future has examined the population questions and its report suggested that we seek a decrease in population growth. The United States is an active participant in the U. N. Conference on the Human Environment to take place in Stockholm in June 1972. There, environmental problems will be dealt with on a worldwide basis for the first time. Last year in the President's Energy Message a new commitment to the development of low-cost nuclear energy sources was made. Availability of abundant energy would allow increased recycling of materials and greater access to materials now too costly to produce. We have initiated a major attack on pollution, a problem just recently recognized as serious, through, for example, the establishment of the Environmental Protection Agency.

The Meadows book and the attention it has been given points out the need for greater coordinated effort on the part of the Federal Government to develop meaningful models that can be used to help illuminate the future implications of complex policy decisions. The resultant models should be subjected to careful scrutiny by experts in the scientific community and their limitations and assumptions made clear before their predictions may be accepted as a significant basis for national policy. I am initiating discussions with the National Science Foundation and other Federal agencies to explore possible mechanisms for expanding our capability in this area; in a manner that will make use of modern computing methodology and envolve experts from all relevant disciplines.

Edward E. David, Jr.
Science Adviser

DRAFT:DGLuenberger:ba 4-18-72

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The Meadows book and the attention it has been given points out the need for greater coordinated effort on the part of the Federal Government to develop meaningful models that can be used to help illuminate the future implications of complex policy decisions. The resultant models should be subjected to careful scrutiny by experts in the scientific community and their limitations and assumptions made clear before their predictions may be accepted as a significant basis for national policy. I am initiating discussions with the National Science Foundation and other Federal agencies to explore possible mechanisms for expanding our capability in this area; in a manner that will make use of modern computing methodology and envolve experts from all relevant disciplines.

Edward E. David, Jr.
Science Adviser

Letters

World Modeling

The scathing review by Martin Shubik (3 Dec., p. 1014) of Jay W. Forrester's book *World Dynamics* is, unfortunately, more than the personal opinion of an angry man. It is the expression of the views of very influential groups of people, which threaten to discredit and suppress a method of forecasting which I consider as of the greatest importance and promise.

There can be no doubt that Forrester's world model is only a first approximation. It lumps together highly industrialized and developing countries. It makes quantitative assumptions about interrelations, and Shubik is of course right in his skeptical remark about their validation by "the acceptance of top decision makers." Such questions are not decided by authority. Forrester's assumptions are validated by their plausibility, and greatly reinforced by the *insensibility* of his results to the details of the assumptions.

It is somewhat hard to understand the violence of the reactions to Forrester's work, of which Shubik's review is only an example. The rational way of rejecting it would be to show that it is so critically dependent on the model, and on the policies which are fed into it, that its predictive value is nil or less than that of intuitive forecasts. To my knowledge this has never been attempted, by any of the critics. Instead they reject it out of hand, intuitively, with angry aspersions at the author and the Club of Rome.

The problem in question is nothing less than the future of mankind. Shall we treat it, as until now, "intuitively," which means, as Forrester rightly remarks, using primitive mental models, and contemptuously reject the help which the computer can give to our thinking? Surely, the rational and responsible way would be to improve the inputs by the collaboration of the widest possible circle of disciplined minds, not only econometricians but also politicians, psychologists, and creative technologists who can make guesses at new inventions which might radically alter the prospects. The costs would be negligible, not only in relation to the importance of the problem, but also in relation to what the United States spends every year on data acquisition.

DENNIS GABOR
Imperial College, London

Shubik's review fails to enlighten the reader concerning Forrester's objectives. Forrester has chosen five quantities, namely, population, natural resources, capital investment, fraction of capital investment in agriculture, and pollution, as quantities which are of most significance in the world system. Mathematically describing interrelations between these quantities, he then programs a digital computer to operate the resulting mathematical model. The trends in our world system indicated by this computer simulation are ominous indeed. Natural resource depletion turns out to be the limiting factor on growth, and population ultimately falls, to the accompaniment of a rise in pollution and a decline in the quality of life. Furthermore, none of the conventional solutions helps matters; for example, removing the natural resource constraint leads to an even more catastrophic pollution crisis and rapid die-off of population. These conclusions parallel the thinking of others both here (*1*) and abroad (*2*) attempting to view the world environmental situation holistically.

The author anticipates criticism of his work, and has ably answered the reviewer's primary objections by pointing out that governments readily concoct legislation which is presumed to correct ills in the social systems but which is in fact based merely on mental images of the real systems, images which are far less accurate than those he has constructed for computer analysis. The reviewer has wandered further onto shaky ground by attempting to liken the author's work to the analysis of RLC circuits. Forrester correctly describes the world system as a complex, nonlinear, multi-loop feedback system, and his programming reflects this. RLC circuits, on the other hand, are not by themselves feedback systems but are simply passive, essentially linear networks of electrical quantities and are of doubtful relevance to the discussion.

Forrester's dynamic model is by his own admission crude; but even crude models often give insight into a problem and serve as stepping-off points for more sophisticated models. That Forrester's model seems to be inherently unstable is a matter for thought, concern, and further research, not ridicule or head burying.

HAROLD H. HEMOND
Department of Applied Science and Engineering, U.S. Coast Guard Academy, New London, Connecticut
RICHARD H. GOODWIN
WILLIAM A. NIERING
Department of Botany, Connecticut College, New London 06320

References

1. "Man in the living environment," report of the Workshop on Global Ecological Problems (Institute of Ecology, Madison, Wis., 1971).
2. A. Lewis, *New York Times*, 14 January 1972, pp. 1 and 8.

. . . A substantial error in interpreting the book results from the reviewer's not taking note of the book's history as given in the preface. His remark "the Club of Rome, which sponsored this work . . . should provide some guidance" implies that the book is a consequence of the sponsored project. The preface clearly states: "On June 29, 1970, I attended a meeting of the Club of Rome in Bern, Switzerland . . . the group was invited to Cambridge . . . a meeting convened on July 20 for ten days of study, presentations, and discussion. The dynamic model of world interactions described in this book was devised in the early part of July to form a basis for discussion at the conference. It must be considered a preliminary effort. . . . As a result of the July meeting, the executive committee of the Club of Rome decided to establish a one-year research program at M.I.T. An international team under the leadership of Professor Dennis L. Meadows is going beyond the model described here to explore more deeply the underlying assumptions and the several major subsystems that form the sectors of the total world system." The content of the book led to the establishment of

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the project at M.I.T. and is not a report on the output of the project. The book was an unsponsored personal effort. The project sponsored by the Club of Rome and the Volkswagen Foundation has been for the purpose of extending the model, modifying and documenting the assumptions, and discussing the inputs as well as the consequences by working with scientific research groups in other institutions who have relevant information and opinions. The published results of the project will begin to appear soon.

JAY W. FORRESTER

Alfred P. Sloan School of Management, Massachusetts Institute of Technology, Cambridge 02139

Unlike many of my colleagues who are extremely skeptical about large-scale simulation, data banks, and the organized use of politico-socioeconomic models, I believe (and am on record as believing) that an effort of the magnitude of the United States space program should be mounted to do this work. Where Forrester and I differ is that, although we may both see the limitations of econometrics and the importance of model building in areas where measures are hard to obtain, we have different views of what is feasible and useful. In my reading of his *Industrial Dynamics* and *World Dynamics* and glancing at *Urban Dynamics,* I have not seen anything to suggest that the models presented are other than extremely simplistic, given the current state of knowledge in the social sciences. I fear that if Forrester, with his drive, energy, and intelligence, were to obtain large funding for his work at the national level, he might easily be the source of a fad for producing grossly oversimplified models, which after a few years would bring about a reaction that would seriously set back progress in simulation, data bank creation, and large-scale social-scientific investigation. . . .

In reply to the specific points in Gabor's letter, I should say first that it appears to me the burden of proof of the relative worth of Forrester's work lies somewhat with its proponents. I have not seen this proof forthcoming. No evidence is given in Forrester's books that his results are insensible to the details of the assumptions. Furthermore, contrary to Gabor's assumption, such insensibility is not always a merit. Those who have worked with industrial, economic, social, or psychological simulations (Orcutt, Simon, Coleman, Abelson, Adelman, Crecine, Clarkson, to name a few) are well aware of the difficulties of obtaining a good first-approximation model. If it is too insensitive to parametric sensitivity analysis, the model is probably concentrating on the wrong variables. If it is highly sensitive, then data sufficiently accurate for the purposes at hand are probably impossible to obtain.

The application of careful dimensional analysis and the specification of good measures in the right dimensions are all difficult and critical. For instance, what is a measure of "welfare"? Even given a measure, what is its operational significance? Answers to questions such as these call for an intimate knowledge of subjects such as economics, sociology, psychology, and political science. Why are so few social scientists referred to by Forrester? Are there none whose knowledge is worth considering when building models of social, political, economic processes? In fact, there are many who have both deep substantive knowledge and the ability to use computers and who are convinced that the computer and computer models are critical for good social scientific exploration. Consider, for example, the Brookings SSRC model, Tinbergen's work on planning, Orcutt's simulation, or Klein's econometric models. Forrester in his writings does not tell us why such other workers' applications, their sensitivity analysis methods and model building, are not as good as his.

I believe that a proper scientific evaluation of the work on planning and forecasting models in the social sciences is of great importance. This, of course, should include Forrester's work. I propose to Gabor, to the Club of Rome, to the AAAS, to NSF, and others that a project be sponsored or at least a conference be held to initiate such an evaluation. It may turn out that Forrester's work is better than, as good as, or worse than that of Balderston and Hoggatt, Clarkson, Kalman Cohen, Coleman, Crecine, Cyert and March, Gordon, Klein, Leontief, Manne, Markowitz, Meyer, Naylor, or Orcutt, to name a few. An examination of Forrester's contribution to this large body of work in such a context could be of benefit to all. It might provide him with the opportunity to join with members of the growing body of social scientists working on social systems. I should be happy to supply him with a list of eminently qualified judges of work of this nature, in the fields of artificial intelligence, computer science, communications, eco-

nomics, future studies, operations research, political science, philosophy of science, psychology, statistics, and other pertinent subjects.

MARTIN SHUBIK
Department of Administrative Sciences, Yale University, New Haven, Connecticut 06520

Test Bias

The letter (24 Dec. 1971, p. 1278) by Kenneth Clark and Lawrence Plotkin was meant to correct what they describe as "three egregious misstatements" in Stanley's article "Predicting college success of the educationally disadvantaged" (19 Feb. 1971, p. 640) where he discussed, among many other studies, one by Cleary (*1*). Clark and Plotkin took out of context a single sentence in the 7½-page article: "Cleary tried to replicate the findings of Clark and Plotkin [*2*] with a better controlled design, but failed." This conclusion referred to Stanley's prior quotation from the Clark and Plotkin study: ". . . Clark and Plotkin . . . had reported results of a study based on 'alumni' classes of the National Scholarship Service and Fund for Negro Students in which they concluded that:

> . . . scholastic aptitude test scores are not clearly associated with college grades. It is suggested that college admissions officers weigh test scores less, since they do not predict the college success of Negro students in the same way they do for whites. This study indicates that motivational factors are probably more important than test scores in the demonstrated superiority of Negro students in completing college."

Stanley was not questioning their conclusion that an able, highly motivated group of black students persisted well to graduation in a variety of interracial colleges during the 1950's. (For example, see note 19 in Stanley's article.) He did, however, cite much evidence—including Cleary's study—that Scholastic Aptitude Test scores and high school records tend to predict the college grades of blacks at least as well as they do those of nonblacks. In their letter Clark and Plotkin disregard this other evidence and thereby imply that Stanley's whole case rests on the Cleary study alone, which they seem to perceive as part of an Educational Testing Service plot against them ("Accustomed as we have become for our study to be the launching pad for ETS papers. . ."). Although one need not defend the professional integrity of researchers at ETS (*3*), we note that neither Stanley's article nor most of the reports he cites were done at ETS. Some of the strongest evidence came from investigations by black non-ETS researchers such as S. O. Roberts, Joseph P. McKelpin, and Charles Leo Thomas and from studies in Illinois, Maryland, Georgia, and the Seven Sisters colleges. Even a glance at the bibliography in the Stanley article would indicate the broad data on which he based his conclusions. (Indeed, only three lines of his paper were devoted to the Cleary article.)

Since Clark and Plotkin have chosen to criticize the Cleary article, let us consider the points they make. Clark and Plotkin say that their data were better than Cleary's because they "had data on over 1200 Negro subjects (with questionnaire response from over 500) drawn from all sections of the country and distributed in hundreds of diverse colleges." The quality of data is, of course, always relative to the purpose they are to serve. For the conclusion of Clark and Plotkin that an admissions officer (who necessarily works within a single institution) should weigh test scores less, distribution of the sample among "hundreds of diverse colleges" is a disadvantage rather than an advantage. For the admissions officer, Cleary's within-college analysis is clearly more relevant. Since Cleary was able to analyze data in only three colleges, she limited her conclusions: "The schools used in this study do not represent the full spectrum of colleges in the United States, so general conclusions cannot be reached." But there are many studies other than Cleary's in which the within-college analysis has been performed, and most of these were reviewed in the Stanley article. With each new analysis, the Clark and Plotkin conclusion becomes less credible.

In their criticism of the Cleary article, Clark and Plotkin persist in their emphasis of correlation coefficients to the exclusion of regression lines. It is well known that the size of a correlation coefficient is a function of the variability of the group: when the range of scores is restricted, the correlations are attenuated. For this reason and others, the comparison of regression lines is a more appropriate analysis. Clark and Plotkin computed no correlation coefficients or regression equations, nor did they even work within colleges. Instead, they pooled college grades from 187 different colleges and

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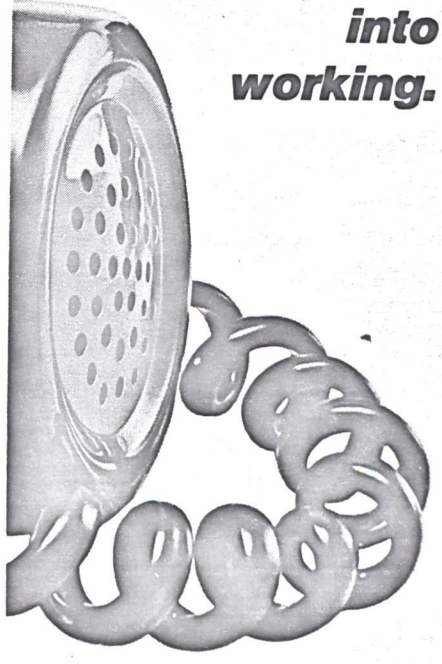

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from many countries who have joined together to find ways to understand better the changes now occurring in the world. The members act as private citizens. They are not in governmental decision-making positions. Their orientation is activist—that is, they wish to do more than study and understand. They wish to clarify the course of human events in a way that can be transmitted to governments and peoples to influence the trends of rising population, increasing pollution, greater crowding, and growing social strife.

At the time of the Bern meeting, The Club of Rome had already planned a project on "The Predicament of Mankind." Preliminary goals, a survey of methodologies, and a statement of the "problematique" had been prepared by Aurelio Peccei, Eduard Pestel, Alexander King, Hasan Ozbekhan, Hugo Thiemann, and others. The objective of the project is to understand the options available to mankind as societies enter the transition from growth to equilibrium. Man throughout history has focused on growth—growth in population, standard of living, and geographical boundaries. But in the fixed space of the world, growth must in time give way to equilibrium. Little is known about the social and economic forces that will accompany the entry into world equilibrium.

The June meeting was held to review the status of the project, which was about to begin. Discussion in the meeting revealed that a suitable methodology had not yet been identified to deal with the broad sweep of human affairs and the ways in which major elements of the world ecology interact with each other. Because the "system dynamics" approach as already developed at the Massachusetts Institute of Technology seemed well suited, the group was invited to Cambridge to determine firsthand if they agreed that the methods then existing would be suitable for the next step in the project. As a result, a meeting convened on July 20 for ten days of study, presentations, and discussion.

The dynamic model of world interactions described in this book was devised in the early part of July to form a basis for discussion at the conference. It must be considered a preliminary effort. But all models will be tentative, for new insights will continue to appear. Because a truly final model of the world system is unlikely ever to be achieved, and because of the widespread interest that has already been expressed in this effort, it seems appropriate to present the existing assumptions and implications in this book.

As a result of the July meeting, the Executive Committee of The Club of Rome decided to establish a one-year research program at M.I.T. An international team under the leadership of Professor Dennis L. Meadows is going beyond the model described here to explore more deeply the underlying assumptions and the several major subsystems that form the sectors of the total world system. Substantial extensions are being made into the dynamics of population, pollution, capital investment, and agriculture. The emerging results promise to extend greatly the understanding of world behavior. As of this writing, the new insights do not alter in any substantial way the broad implications reported here.

The continuing project, as well as the July conference, has been made possible by financial support to The Club of Rome from the Volkswagen Foundation (Stiftung Volkswagenwerk) in Germany.

Only broad aspects of the world system are discussed here, not the difficulties of implementing the changes that will be necessary if the present course of human events is to be altered. Many important variables are omitted. Aggregation is at such a high level that the distinctions between developed and underdeveloped countries do not appear explicitly. Most of the concepts in the world model reflect the attitudes and motivations of the recent past and present. Therefore the book does not incorporate the possible changes in human aspirations and values that might come from widespread recognition of the predicament facing mankind. All these and others are issues for future investigation. I hope this book contributes to the sense of urgency and also that it points to an effective direction for work by others who may choose to explore the alternatives for the future.

In spite of the tentative nature of the world model described here, various conclusions are drawn from it. Man acts at all times on the models he has available. Mental images are models. We are now using those mental models as a basis for action. Anyone who proposes a policy, law, or course of action is doing so on the basis of the model in which he, at that time, has the greatest confidence. Having defined with care the model contained herein, and having examined its dynamic behavior and implications, I have greater confidence in this world system model than in others that I now have available. Therefore, this is the model I should use for recommending actions. Those others who find this model more persuasive than the one they are now using presumably will wish to employ it until a better model becomes available.

It is to be hoped that those who believe they already have some different model that is more valid will present it in the same explicit detail, so that its assumptions and consequences can be examined and compared. To reject this model because of its shortcomings without offering concrete and tangible alternatives would be equivalent to asking that time be stopped. But the world will continue to turn. We always use the most acceptable model at any point in time. But how should we proceed so that the most acceptable model is also the best one that is available? We should try for three things. First, the best *existing* model should be identified at each point in time. Second, the best currently existing model should be used in preference to traditional models that may be less clear and less correct. Third, aggressive effort should be devoted to a continual improvement in the available models of the world system.

It seems traditional for explicit models of social systems to be greeted by vague criticisms about their lack of perfection. Instead, we need equally explicit alternatives with a demonstration that the alternative leads to a *different* and *more plausible* set of conclusions. By proposal and counter proposition our understanding of social systems can advance.

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