TECHNOLOGY ASSESSMENT AND GENETICS

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No one—not even the most brilliant scientist alive today—really knows where science is taking us. We are aboard a train which is gathering speed, racing down a track on which there are an unknown number of switches leading to unknown destinations. No single scientist is in the engine cab, and there may be demons at the switch.[1]

There can be no question that many of the benefits of modern life are the direct result of scientific research and technological development.[2] During the past decade, however, it has become increasingly apparent that technology is not an unmixed blessing. One attempt to cope with the mixed character of technological development is the technology-assessment movement.

CONCEPT OF TECHNOLOGY ASSESSMENT

The term "technology assessment" (TA) seems to have been coined in a report of the House Subcommittee on Science, Research, and Development.[3] Due primarily to the tireless efforts of the Subcommittee and its chairman, Emilio Q. Daddario, the concept of TA gradually spread into the academic world, where it was picked up in particular by engineers and physicists. During the year 1969 a scholarly literature on the subject of TA began to develop; indeed, it is possible to identify ten recent reports of books which have achieved almost-canonical status within the movement.[4] Late in 1971 an International Society for Technology

[1] Ralph E. Lapp, *The New Priesthood: The Scientific Elite and the Uses of Power* (New York: Harper & Row, 1965) p. 29.

[2] In this essay science, whether basic or applied, is defined as an information function. Technology, on the other hand, is conceived as the development and social use of scientific information. In practice it is not always possible to draw a clear line between science and technology. See U.S. Congress, House, Committee on Science and Astronautics, "Science Policy: A Working Glossary," Prepared for the Subcommittee on Science, Research, and Development by the Science Policy Research Division, Congressional Research Service, Library of Congress (Washington, D.C.: U.S. Government Printing Office, 1972) p. 53.

[3] U.S. Congress, House, Committee on Science and Astronautics, "Inquiries, Legislation, Policy Studies Re: Science and Technology," Second Progress Report of the Subcommittee on Science, Research, and Development, 89th Congress, second session (Washington, D.C.: U.S. Government Printing Office, 1966) pp. 27–28. Mr. Philip B. Yeager, Counsel to the Subcommittee, is generally given credit for having coined the term "technology assessment."

[4] The most important works on TA are the following: (A) Four reports to the Subcommittee on Science, Research, and Development of the House Committee on Science and

Assessment was formed to "contribute to the structuring, study, control and resolution of the world's technological challenges and dilemmas."[5] The Society, in turn, began publishing a quarterly journal, *Technology Assessment*, in the summer of 1972.

What precisely is meant by the term TA? Joseph F. Coates, a program manager in the National Science Foundation, offers the following concise explanation: "Technology assessment may be defined as the systematic study of the effects on society that may occur when a technology is introduced, extended, or modified, with special emphasis on the impacts that are unintended, indirect, and delayed."[6]

Two phrases in Coates's definition merit brief elaboration. Practitioners of TA generally construe the idea of "effects on society" in rather broad terms. Their particular concern is to take into account environmental and other social consequences of technology and to avoid an exclusive focus on economic profit and loss. When Coates employs the terms "unintended, indirect, and delayed" to describe certain of these consequences, he alludes to another major emphasis within the TA-movement, namely, second-order consequences. Immediate, direct, and intended effects of technological change are generally termed first-order consequences. The primary focus of TA is on the less ob-

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Astronautics: (1) Science Policy Research Division, Congressional Research Service, Library of Congress, *Technical Information for Congress* (April 25, 1969; revised, April 15, 1971); (2) National Academy of Sciences, *Technology: Processes of Assessment and Choice* (July, 1969); (3) Committee on Public Engineering Policy, National Academy of Engineering, *A Study of Technology Assessment* (July, 1969); (4) National Academy of Public Administration, *A Technology Assessment System for the Executive Branch* (July, 1970). (B) Two volumes of hearings before the same Subcommittee: (5) *Technology Assessment* [1969] and (6) *Technology Assessment—1970.* (C) Two books: (7) Raymond A. Bauer, *Second-Order Consequences: A Methodological Essay on the Impact of Technology* (Cambridge, Mass.: M.I.T. Press, 1969); (8) Raphael G. Kasper, ed., *Technology Assessment: Understanding the Social Consequences of Technological Applications* (New York: Praeger, 1972). (D) Two other studies: (9) Martin V. Jones *et al.*, *A Technology Assessment Methodology* (7 vols.; Washington, D.C.: MITRE Corporation, 1971); (10) Vary T. Coates, *Technology and Public Policy: The Process of Technology Assessment in the Federal Government* (2 vols.; Washington, D.C.: Program of Policy Studies in Science and Technology, George Washington University, 1972). The best and most comprehensive bibliographical essay on TA appears in the first issue of the journal *Technology Assessment*: Genevieve J. Knezo, "Technology Assessment: A Bibliographic Review," *Technology Assessment* 1 (1972) 62–83.

[5] This quotation is taken from a descriptive brochure entitled "The International Society for Technology Assessment." The American office of I.S.T.A. is located in Suite 5038, 1629 K Street, NW, Washington, D.C. 20006.

[6] "Technology Assessment: The Benefits ... the Costs ... the Consequences," *Futurist* 5 (1971) 225.

vious social impacts of technology, that is, on second-, third-, and higher-order consequences.[7]

Writers on TA have distinguished several subtypes of assessment. For example, an obvious distinction can be drawn between retrospective and prospective analyses, between studies of the past and of the future. Closely related is the distinction between problem-initiated and technology-initiated assessments. The former type surveys currently-available technologies in quest of a solution to a specific problem; the latter mode of assessment attempts to follow through time "the inherently proliferating set of impacts" of a particular technology.[8]

If the above definitions and classifications indicate the general contours of TA, they do not yet give a clear picture of its methodology. There is, in fact, no single universally-accepted method for performing TA. Perhaps the most thorough and systematic attempt to formulate such a methodology is a study written by Martin V. Jones, an economist at the MITRE Corporation.[9] In his programmatic essay Jones lists seven major steps to be taken in performing a comprehensive technology assessment:

> Step 1. Define the assessment task: establish the scope of the inquiry.
>
> Step 2. Describe relevant technologies: outline the state of the art in the major technology being assessed as well as in related technologies.
>
> Step 3. Develop state-of-society assumptions: identify and describe the major nontechnological factors influencing the application of the relevant techniques.
>
> Step 4. Identify impact areas: list the societal characteristics that will be most influenced by the application of the assessed technology.
>
> Step 5. Make preliminary impact analysis: trace and integrate the various specific impacts of the assessed technology upon society.
>
> Step 6. Identify possible action options: develop and analyze various programs of obtaining maximum public benefit from the assessed technologies.
>
> Step 7. Complete impact analysis: analyze the degree to which each action option would alter the specific societal impacts (listed in Step 5) of the assessed technology.[10]

The method outlined by Jones will now be described in somewhat greater detail. In taking Step 1 the assessor decides whether to attempt a total-impact assessment or whether to be content with a partial as-

[7] Bauer, *Second-Order Consequences, passim.*

[8] Committee on Public Engineering Policy, National Academy of Engineering, *A Study of Technology Assessment*, p. 5.

[9] *A Technology Assessment Methodology* 1: *Some Basic Propositions* (hereafter cited as *TAM* 1).

[10] Adapted from Jones, *TAM* 1, 26.

sessment. Having made that choice, he proceeds to Step 2, a precise description of the technology under consideration. According to Jones, this description should answer the following questions: (1) What is the current state of the art in the assessed technology? (2) What is the current state of the art in related or supporting technologies? (3) What technical breakthroughs are needed? (4) What future developments in the state of the art are anticipated and within what time frame? (5) What are the current and prospective uses and applications of the assessed technology?[11]

Steps 3 and 4 refer to the complex reciprocal relationships between society and technology. In Step 3 the assessor of technology attempts to project general trends in the society of the future and to predict how these social phenomena might accelerate or retard the development and application of the technology in question. In Step 4 the process is reversed: one seeks to identify the general spheres of human life which are most likely to be affected by future developments in the assessed technology. These general spheres, or major impact categories, include personal and community values, the environment, demographic trends, social goals and problems, economic factors, and institutions.[12]

Steps 1–4 are preparatory to Step 5, which is the primary goal of the assessment. Here the assessor attempts to anticipate and describe specific consequences of technological development. A helpful framework for this impact-analysis is provided by Jones in his methodological essay:

KEY IMPACT QUESTIONS[13]

Questions	Types of Answers
Technology	
Development	Describe the initial effect of the development: to lower cost, to improve performance, etc.
Application	Describe the use to which this development is put.

[11] Adapted from Jones, *ibid.*, pp. 29, 46.
[12] Jones, *ibid.*, p. 67.
[13] *Ibid.*, p. 82 (slightly revised). Reprinted by permission of the author.

Questions	Types of Answers
Social	
Social Impact	Identify the first level impact of the application.
Impact Characteristics	
Affected Group	What social group will be most affected: old or young, rich or poor, workers or managers, the sick or well, etc.?
How Affected	For better or worse, and in what specific way?
Likelihood	E.g., 50–50 chance.
Timing	Estimate dates both for initial impact and later widespread effect.
Magnitude	Preferably in dollars, percentage increase, number affected, etc., rather than adjectives like "large," "small," etc.
Duration	Indicate whether initial impact will improve or worsen and for how long.
Diffusion	Breadth and depth of impact. An unfavorable impact of equal total magnitude (e.g., dollar volume) that is concentrated on a few people will cause more social distress than if it were diffused through many people.
Source	Indicate the source (industry, Federal government, foreign source, etc.) from which the development leading up to this impact originates.
Controllability	Is it likely that a public program could heighten or dampen the impact generated by the technology?

The final two steps in a technology assessment consider whether various types of monitoring- or control-mechanisms could modify the rate or direction of technological development and thus alter its social impact. Among possible action options the most important are methods of allocating research and development funds; other financial incentives, including taxes; legislation; court action; mass-media publicity; education; and the construction of new systems or facilities.[14]

In addition to the how of TA it is necessary to consider the who-question: Who should participate in the complex process of assessing technology? Much of the current initiative for systematic TA comes from the Congress, some of whose members fear that the executive branch is gaining a monopoly over scientific information. Currently under debate is a bill which would establish a Congressional Office of Technology Assessment, modeled on the pattern of the General Accounting Office.[15] Other possible forums for TA include departments and administrative agencies in the executive branch, the courts, industry, international organizations, professional societies, *ad hoc* task forces, research institutes, and university-based interdisciplinary research teams.[16]

Perhaps equal in importance to the locus of TA is the composition of the group which makes the assessment. Self-evidently, research scientists from the relevant physical or life sciences must be involved. The presence of engineers on the assessment team frequently serves to bridge the gap between research and application. During recent years there has also been increasing sentiment in favor of including social scientists in the assessment process. In addition, some advocates of TA have ventured to suggest participation by "concerned individuals outside science: industrial executives, lawyers, clergymen, and journalists."[17]

Even if TA sounds plausible as a proposal and a theory, one must raise the practical question: Has TA been tried, and, if so, with what degree of success? The answer, in brief, is that until now very few full-scale assessments have been attempted. Pilot studies have made par-

[14] Adapted from Jones, *TAM* 1, 102.

[15] Deborah Shapley, "Office of Technology Assessment: Congress Smiles, Scientists Wince," *Science* 175 (March 3, 1972) 970–73.

[16] Emilio Q. Daddario, "Technology and the Democratic Process," *Technology Review* 73 (July-August, 1971) 19–23; Don E. Kash and Irvin L. White, "Technology Assessment: Harnessing Genius," *Chemical and Engineering News*, November 29, 1971, pp. 40–41.

[17] John Lear, "Predicting the Consequences of Technology," *Saturday Review*, March 28, 1970, p. 44; cf. Committee on Public Engineering Policy, National Academy of Engineering, *A Study of Technology Assessment*, p. 4.

tial assessments of the following present or future technologies: sea farming, mechanized teaching aids, computer-communications networks, industrial enzymes, microwave diodes, and the supersonic transport.[18] Problems which have been assessed in a preliminary way include: automotive emissions, water pollution through domestic wastes, the Alaska pipeline, and a snow-enhancement project for the Colorado River Valley.[19] Only in a few cases—for example, the Jamaica Bay-Kennedy Airport Study—can one speak of a comprehensive or total-impact assessment.[20]

ASSESSMENT OF BIOMEDICAL TECHNOLOGY

As the foregoing examples illustrate, TA has until now been concentrated on two major areas: environmental problems and developments in the physical sciences. The field of biomedical technology has been almost totally ignored.[21] In her comprehensive review of TA in the federal government Vary T. Coates noticed this gap in current TA-studies and voiced concern about the possible long-term consequences of such neglect:

> Biomedical technologies, especially bioengineering and pharmacology, are producing or are likely to produce some of the most profound effects on social mores and behavior of the future. It is likely that public policy issues will soon arise from this area in great numbers, and that these policy issues will be profoundly interwoven with religious, social, economic, cultural, and ideological factors. Very little anticipatory assessment is being done and almost none by the federal agencies which are financially supporting much of the scientific research driving this technological development, or which may be called upon to

[18] Jones *et al.*, *TAM*, Vols. 3, 4, and 5; Committee on Public Engineering Policy, National Academy of Engineering, *A Study of Technology Assessment*, pp. 37–75, 107–42; Raymond Bowers and Jeffrey Frey, "Technology Assessment and Microwave Diodes," *Scientific American* 226 (February, 1972) 13–21; George N. Chatham, "The Supersonic Transport," in Science Policy Research Division, Congressional Research Service, Library of Congress, *Technical Information for Congress*, 2nd ed., pp. 685–748.

[19] Jones *et al.*, *TAM*, Vols. 2 and 6; J. Coates, "Technology Assessment," p. 229.

[20] Steven Ebbin, "The Jamaica Bay Study: A Case History," *Futurist* 6 (February, 1972) 27–28.

[21] Of 206 citations in Genevieve J. Knezo's bibliographical essay, only three (nos. 140, 169, and 190) refer to articles which discuss biomedical technology ("Technology Assessment: A Bibliographic Review," pp. 80–82). In her study of TA and the federal government Vary T. Coates was able to discover only three examples of already-completed assessments in biology or medicine; the studies dealt with cardiac replacement, abortion, and the use of drugs in the treatment of behaviorally disturbed children (*Technology and Public Policy* 1, chap. 3, pp. 17–22). A general attempt to anticipate the social impact of future developments in both biology and physics is: Theodore J. Gordon and Robert H. Ament, *Forecasts of Some Technological Developments and Their Societal Consequences*, IFF Report R-6 (Middletown, Conn.: Institute for the Future, 1969).

exercise whatever regulatory authority society may choose to impose. Public opinion and political leadership will therefore lack a firm base of information and issue analysis to guide public discussion, and action will very likely be taken in a crisis situation, with a corresponding plethora of irrational and uninformed charges and countercharges. Or no action at all will be taken, until social change is irreversible and irremediable. Therefore the opportunity for positive social direction of a burgeoning but still rudimentary technology will be lost, and with it the opportunity to identify societal options and the opportunity to influence developments along socially and individually desirable paths.[22]

A partial explanation for the lack of TA in the biomedical field may be that there are significant differences between the physical sciences and the life sciences. For example, technologies based on research in the life sciences are usually applied to human beings by licensed medical practitioners, that is, by a unique social group with a distinctive tradition and code of ethics. Successful TA in the biomedical field is thus heavily dependent on active co-operation by the medical profession. In addition, developments in biomedical technology are supported primarily by public funds; according to one estimate, approximately two thirds of all money spent on research and development in biomedicine and health comes from the federal government. Thus, advances in biomedical technology already reflect public-policy decisions to a much greater extent than do technical advances in the field of physics and physical engineering.[23]

A third distinction between the physical and life sciences is somewhat more elusive. It could perhaps be called a difference in the intimacy of effects. The development of new products and devices has always had a profound impact upon society. However, when biomedical technology is applied directly to man, to human flesh, the stakes seem to be higher, and human concern is correspondingly greater. Hans Jonas has captured the significance of this difference in a few terse lines:

> Among the sciences that progressively contributed to the technological revolution, *biology* has so far not figured. Are we perhaps on the verge of another—conceivably the last—stage of that revolution, based on biological knowledge and wielding an engineering art which, this time, has man himself for an object? This has become a theoretical possibility with the advent of molecular biology and its understanding of genetic programming. . . .[24]

These differences between the physical and life sciences raise a fun-

[22] *Technology and Public Policy* 1, 26–27.

[23] For the distinctions and information contained in this paragraph I am indebted to a personal communication from Dr. Leon R. Kass.

[24] "The Scientific and Technological Revolutions: Their History and Meaning," *Philosophy Today* 15 (1971) 99.

damental question: Can a single methodology be employed to evaluate technological developments in both fields? To rephrase the issue, can the TA-methodology which was outlined in Part 1 be applied to biomedical technologies?

The thesis of this essay is that the same methodology, with minor adjustments, is applicable to the biomedical field. Preliminary evidence in support of this thesis is contained in a forthcoming study made by the Committee on the Life Sciences and Social Policy of the National Research Council.[25] This study, coordinated by Dr. Leon R. Kass, investigates present and potential developments in four biomedical technologies. According to Dr. Kass, the Committee considered the following set of issues in selecting the technologies and in making its assessments: (1) stage of development of the technology; (2) scale of use; (3) relation to other technologies; (4) ease of monitoring and control; (5) reversibility; (6) nature and scope of societal consequences for users of the technology and for society; and (7) questions of public policy.[26] On the whole, the Committee's method of study parallels precisely the progression of thought in the TA-methodology outlined above. More specifically, the seven issues discussed in the Committee report are virtually identical to those raised in Steps 2, 5, and 6 of the proposed TA-methodology.

There are numerous developments in biomedical technology which could be made the subject of assessments. The pioneering study of the Committee on the Life Sciences and Social Policy concentrates on four technologies: *in vitro* fertilization; techniques for predetermining the sex of children; "techniques to slow the biological process of aging"; and "techniques for the modification and control of the nervous system and behavior."[27] Other innovations predicted by experts in biomedicine include the following: implantable artificial hearts and other mechanical organs; safe, inexpensive contraceptive agents capable of being administered on a mass scale; asexual reproduction, or cloning, of human beings; chemotherapeutic cures for various types of cancer; an artificial placenta, which would allow extrauterine development of the fetus; methods for stimulating the regeneration of the central nervous system, organs, or limbs; and techniques for the repair or alteration of specific genes.[28]

[25] The study, which will appear in January of 1973, is provisionally titled *Assessing Biomedical Technologies: Prospects and Problems* (A Study by the Committee on the Life Sciences and Social Policy, Division of Behavioral Sciences, National Research Council, National Academy of Sciences).

[26] For the information contained in this paragraph I am indebted to a personal communication from Dr. Leon R. Kass.

[27] Personal communication from Dr. Kass.

[28] Gordon and Ament, *Forecasts*, pp. 24–28.

ASSESSMENT OF GENETIC TECHNOLOGY

A significant subcategory of biomedical technology is based on the science of human genetics and allied disciplines. Indeed, it can be argued that recent developments in the general field of genetics are comparable in importance to the discovery and utilization of atomic energy a generation ago. In the words of Dr. Bentley Glass:

> The discoveries of molecular biology and genetics during the past twenty years are now generally acclaimed to be the most significant basic scientific advances of our present generation, just as the understanding of the focus of nuclear energy in the atom was that of the preceding generation. Like the application of nuclear energy to both destructive and constructive uses, the application of the spectacular finding that deoxyribonucleic acid (DNA) is the chemical basis of heredity offers man a magnificent extension of power over nature and at the same time lays on his conscience a frightening responsibility in the use of that power.[29]

Strictly defined, the term "genetic technology" includes the following present or potential developments: the detection of genetic defects in the unborn through amniocentesis; techniques for identifying, or screening, heterozygous carriers and homozygous victims of genetic disease; and gene repair through DNA therapy.[30] A somewhat broader definition of genetic technology might encompass as well the techniques of *in vitro* fertilization and cloning, both of which have obvious eugenic applications.[31] In the paragraphs which follow, this second, more comprehensive definition of genetic technology is employed.

Until now, no published study has attempted a comprehensive assessment of any of the five genetic technologies noted above.[32] However, numerous books and articles have discussed the possible long-term impact of genetic technology in a mode *akin to* that of TA. In my view, these studies—which might be called partial assessments—constitute important building blocks for future efforts to provide comprehensive assessments in the field of genetic technology.[33]

[29] "Human Heredity and Ethical Problems," *Perspectives in Biology and Medicine* 15 (Winter, 1972) 237.

[30] Richard Roblin, "Some Recent Developments in Genetics," THEOLOGICAL STUDIES 33 (September, 1972) 403-10.

[31] Of these five technologies the first two, amniocentesis and genetic screening, are currently in use. Technically speaking, *in vitro* fertilization in humans seems to await only the solution of certain minor difficulties. The application of cloning and DNA therapy to man, on the other hand, faces major technical obstacles; these techniques should therefore be regarded as future possibilities rather than as imminent developments.

[32] The forthcoming study of the Committee on the Life Sciences and Social Policy includes an extended, systematic analysis of *in vitro* fertilization. See nn. 25 and 27 above.

[33] The following are among the most important currently-available studies in this field: the series of articles which appeared in the September, 1972, issue of THEOLOGICAL

Two examples will serve to illustrate the close resemblance between these studies and the seven-step TA-methodology outlined above. In a lecture given at the Kennedy Foundation's International Symposium on Human Rights, Retardation, and Research and subsequently published in the *Journal of the American Medical Association*, Paul Ramsey discusses the issue of *in vitro* fertilization.[34] After defining the scope of his topic and briefly sketching the current state of the art, Ramsey notes a major nontechnological factor which in his view should inhibit the application of this particular genetic technology to human beings, namely, certain generally accepted rules or codes concerning human experimentation. In the second part of his essay Ramsey turns from this deontological argument to a more teleological mode of analysis, arguing that the general impact of *in vitro* fertilization in human beings would be to replace reproduction with manufacture and to pervert the traditional function of the medical profession.[35]

More specific social impacts are discussed by Professor Ramsey under the rubric of the "thin end of the wedge" argument. In an eloquent passage Ramsey argues that the application of *in vitro* fertilization to human beings would have serious detrimental second-order consequences:

To be valid... the wedge argument need not, like my reasons drawn from medical ethics, attempt to show the inherent immorality of a given sort of action

STUDIES; Peter G. Condliffe *et al.*, eds., *Ethical Issues in Genetic Counseling and the Use of Genetic Knowledge* (New York: Plenum, 1972); Charles E. Curran, "Theology and Genetics: A Multi-Faceted Dialogue," *Journal of Ecumenical Studies* 7 (1970) 61-89; Robert G. Edwards and David J. Sharpe, "Social Values and Research in Human Embryology," *Nature* 231 (May 14, 1971) 87-91; Glass, "Human Heredity" (see n. 29 above); James M. Gustafson, Richard Roblin, Marc Lappé, *et al.*, "Ethical and Social Issues in Screening for Genetic Disease," *New England Journal of Medicine* 286 (May 25, 1972) 1129-32; Michael Hamilton, ed., *The New Genetics and the Future of Man* (Grand Rapids, Mich.: Eerdmans, 1972); Maureen Harris, ed., *Early Diagnosis of Human Genetic Defects: Scientific and Ethical Considerations*, Fogarty International Center Proceedings, no. 6 (Washington, D.C.: U.S. Government Printing Office, 1971); Leon R. Kass, "Babies by Means of In Vitro Fertilization: Unethical Experiments on the Unborn?" *New England Journal of Medicine* 285 (November 18, 1971) 1174-79; Leon R. Kass, "Making Babies—the New Biology and the 'Old' Morality," *Public Interest*, no. 26 (Winter, 1972) 18-56; Paul Ramsey, "Shall We 'Reproduce'? I. The Medical Ethics of In Vitro Fertilization; II. Rejoinders and Future Forecast," *Journal of the American Medical Association* 220 (June 5, 1972) 1346-50; (June 12, 1972) 1480-85; Paul Ramsey, *Fabricated Man: The Ethics of Genetic Control* (New Haven: Yale Univ. Press, 1970); James R. Sorenson, *Social Aspects of Applied Human Genetics*, Social Science Frontiers, no. 3 (New York: Russell Sage Foundation, 1971). For further bibliography and penetrating analysis of several of the works cited above, see the essay of Richard A. McCormick in the September, 1972, issue of THEOLOGICAL STUDIES.

[34] "Shall We 'Reproduce'?" (see n. 33 above). [35] *Ibid.*, pp. 1347-49, 1480-82.

or practice. It need only show that if we do this particular action or permit or encourage a particular practice (perhaps because of undeniable immediate values, e.g., enabling a woman to have a child) we will influence others and cause ourselves to take following steps that in foreseeable succession add up to immense disvalue for the human community. So we shall have to assess in vitro fertilization as a long step toward Hatcheries, i.e., extra-corporeal gestation, and [toward] the introduction of unlimited genetic changes into human germinal material while it is being cultured by the Conditioners and Predestinators of the future.[36]

Ramsey does not propose the adoption of any specific action option to forestall such possible developments, but the very publication of his essay in a leading medical journal constitutes an effort to educate a significant group of decision-makers and thus to alter or avert the potential impact of *in vitro* fertilization on society.

A second example of partial TA in the field of genetics is contained in a recent article by Bentley Glass entitled "Human Heredity and Ethical Problems."[37] Again in this essay one can easily discover the seven steps of Martin Jones's suggested TA-methodology. After defining the scope of his study, Dr. Glass devotes a great deal of attention to describing the state of the art in genetics and molecular biology. According to Glass, the techniques of tranduction, amniocentesis, and genetic screening have made possible significant advances in euphenics[38] and negative eugenics. Such methods pale, however, in comparison with Glass's list of potential developments in positive eugenics, or genetic engineering: selective breeding, *in vitro* fertilization, embryo transfer, gestation in an artificial placenta, laboratory cultivation of human reproductive organs, cloning, genetic surgery, and gene transfer.[39]

Glass notes that several nontechnological factors affect the development or application of the various genetic technologies. Inhibiting factors are the expense of currently-available tests, ethical objections to abortion, the small number of scholars in certain critical disciplines, and society's lack of unanimity on a definition of genetic superiority. On the other hand, Glass observes, the economic cost of caring for persons afflicted with genetic disease tends to push society toward more rapid adoption of available genetic techniques.[40]

In the opinion of Glass, the general impact of employing genetic-engineering techniques would be to help mankind avoid global disaster.

[36] *Ibid.*, p. 1481. [37] See n. 29 above.

[38] Euphenics can be defined as the effort to compensate for a genetic defect by controlling the phenotype rather than the genotype; for example, diabetics use insulin as a compensatory measure.

[39] Glass, "Human Heredity," pp. 238–43, 246–49.

[40] *Ibid.*, pp. 240, 247, 242, 251–52, 241–42.

Without such techniques, he argues, the human race would at best suffer gradual genetic deterioration; at worst, "if in the aftermath of dreadful nuclear war, survivors are unable to provide the necessary artifices—drugs, surgery, and prosthetic devices—to maintain life in spite of their genetic burdens, mankind may perish."[41] Glass also lists several specific impacts which would probably result from the widespread application of present and future genetic technology: "a complete liberation of the sexual life from its relationship to reproduction"; "greater freedom of choice in new respects"; and recognition of the "right of every person to be born physically and mentally sound, capable of developing fully into a mature individual."[42]

Certain possible action steps are mentioned or recommended during the course of Glass's essay; these include mandatory sterilization for retinoblastoma patients, obligatory abortion of seriously defective fetuses, routine genetic testing of all newborn infants, and a licensing procedure to limit the number of children born to each couple.[43] The intent of these measures would not be to alter the societal impacts of genetic technology. Rather, if I understand Glass correctly, their purpose would be to insure that the desired impacts did in fact occur.

In the concluding paragraph of "Human Heredity and Ethical Problems," Glass issues a ringing appeal for broad, interdisciplinary involvement in the assessment of technology.

> I have asked many questions which cannot at present be answered. I predict a future in which many cherished values of our society and many ethical standards will be questioned or superseded. It is not sufficient to have a few scientists raise such issues.... Only a prolonged and profound attention by many of the wisest men of our times, men of philosophy and religion, students of society and of government, and representatives of the common interests of men throughout the world, together with teachers and scientists, may achieve a wise and sober solution of the crisis of values evoked in our world by scientific discoveries and their applications.[44]

The foregoing analysis of the essays by Ramsey and Glass tends to confirm the thesis that the TA-methodology is applicable, at least in principle, to the assessment of biomedical technology. The diametrically-opposed conclusions of Ramsey and Glass serve to underline the relatively modest role of the TA-methodology: it functions as a formal aid to systematic analysis; in no sense, however, does it predetermine the assessor's final evaluation of a particular technology.

A THEORETICAL PERSPECTIVE ON TECHNOLOGY ASSESSMENT

This concluding section seeks to appraise TA from the standpoint of

[41] *Ibid.*, p. 246.
[42] *Ibid.*, pp. 253, 252.
[43] *Ibid.*, pp. 242, 252, 240, 250–51.
[44] *Ibid.*, p. 253.

moral philosophy and Christian ethics. It begins by investigating the intellectual-historical roots of TA, then proceeds to note possible strengths and weaknesses of the TA-methodology.

Without question, I think, the intellectual roots of the TA-movement are to be found in the ethical tradition known as utilitarianism.[45] This heritage can be traced both generally and specifically. The general connection of the TA-movement to utilitarianism has perhaps been mediated through social scientists, several of whom have been deeply involved in developing the theoretical foundations of TA.[46] For a variety of reasons, scholars in the social sciences generally tend toward a utilitarian normative theory. In the words of Braybrooke and Lindblom:

> ... Utilitarianism, at least in the English-speaking world, is the school toward which most social scientists are inclined, if they are inclined toward any. There are historical reasons for this inclination: Important branches of social science, among them economics and sociology, grew out of utilitarian preoccupations. There is also a natural convergence in preoccupations between utilitarianism and social science. Utilitarianism, after all, insists more strongly than any other ethical theory on forcing moral judgments to the test of facts—the facts of social science.[47]

To this general connection between TA and utilitarianism a more specific link can be added. When it focuses on the second-order consequences or social effects or impacts of technology, the TA-movement clearly identifies itself as a utilitarian school of thought. At times the very words employed in assessing social consequences are reminiscent of classical utilitarianism. For example, the key impact questions listed by Martin Jones (in the chart reproduced above) are virtually identical to Jeremy Bentham's categories for measuring the effects of an action. According to Bentham, seven circumstances must always be taken into account: intensity, duration, certainty or uncertainty, propinquity or remoteness, fecundity, purity, and extent.[48]

The type of utilitarianism espoused by the TA-movement is both comprehensive and rather sophisticated. Unlike Bentham, who tended to reduce all ethical argument to a calculus of pleasure and pain,[49] theo-

[45] For a succinct characterization of classical utilitarianism, see John Rawls, *A Theory of Justice* (Cambridge, Mass.: Harvard Univ. Press, 1971) pp. 22–27.

[46] For example, of the seventeen members who participated in the National Academy of Sciences' study of TA, seven were social scientists (*Technology: Processes of Assessment and Choice*, pp. 151–63). Martin Jones, who developed the comprehensive TA-methodology surveyed above, is an economist.

[47] David Braybrooke and Charles E. Lindblom, *A Strategy of Decision: Policy Evaluation as a Social Process* (New York: Free Press, 1963) pp. 205–6.

[48] *An Introduction to the Principles of Morals and Legislation*, chap. 4, par. 4.

[49] *Ibid.*, chaps. 1 and 3.

reticians of TA are willing to take into account a wide variety of consequences—economic, social, political, environmental, legal, and moral.[50] To phrase the same point in more general terms, the TA-movement is not necessarily committed to any particular theory of nonmoral value; rather, it seems willing to accept the positive worth of a plurality of values.[51] Advocates of TA also realize full well the complexity of the task which is to be accomplished. In its final report the Panel on Technology Assessment of the National Academy of Sciences listed numerous "problems and pitfalls" of the TA-enterprise, including shortcomings of modes of analysis, failures of imagination, deficiencies in the data base, and institutional constraints.[52]

One can, I think, be profoundly grateful for the positive contributions of the TA-movement. In the first place, it has introduced a broadened perspective into the analysis of technological development. Most traditional assessments of technology have been focused almost exclusively on internal costs and benefits. In the words of the National Academy of Sciences panel, "With few exceptions the central question asked of a technology is what it would do (or is doing) to the economic or institutional interests of those who are deciding whether or how to exploit it."[53] In contrast, the TA-movement urges that this traditional calculus be supplemented by a humane evaluation of external social consequences.

The flexibility of the TA-methodology is also a point in its favor. As noted above, the employment of this method does not commit the assessor either to a particular value-theory or to a predetermined evaluation of a particular technology. The methodology acknowledges a reciprocal influence of technology and society, thus avoiding any commitment to a partisan ideological position.[54] It is also sufficiently comprehensive to allow for consideration of a variety of nontechnological factors, such as values, institutions, education, and political action.[55]

Third, the TA-methodology lays the foundation for an expanded concept of moral responsibility. Its over-all thrust is to hold men accountable for the remote, as well as the immediate, consequences of their decisions and actions. Spatially interpreted, this concept of responsibility could easily include members of the human community living in other nations.[56] Temporally extended, TA would serve to protect the inter-

[50] National Academy of Sciences, *Technology: Processes of Assessment and Choice*, pp. 29-30.

[51] For general discussions of value-theory, see William K. Frankena, *Ethics* (Englewood Cliffs, N.J.: Prentice-Hall, 1963) pp. 63-77; and G. E. Moore, *Ethics* (New York: Oxford Univ. Press, 1965) pp. 96-108.

[52] *Technology: Processes of Assessment and Choice*, pp. 43-71; cf. pp. 29-32.

[53] *Ibid.*, p. 26 (italics removed); cf. pp. 53-54, 67.

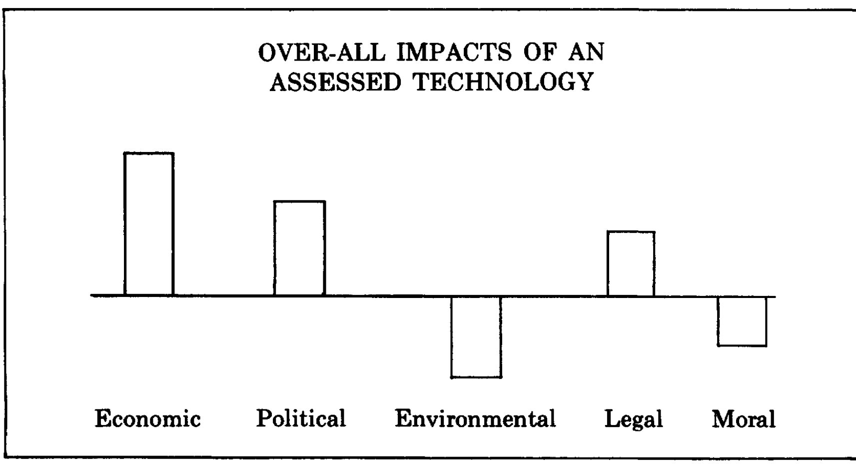
[54] See Steps 2 and 3 in Jones's methodology. [55] See Steps 3 and 6.

[56] Dennis Livingstone, "International Technology Assessment and the United Na-

ests of future generations.[57] To rephrase the point in theological terms, the TA-methodology calls to our attention a whole new group of neighbors, toward whom concern and love can and should be directed.

Without denying these positive contributions of TA, one can, in my view, also raise certain fundamental questions about the TA-methodology. First, to what extent should policy or morality be based on an assessment of possible consequences? Practitioners of TA are already keenly aware of this problem; in fact, one study of TA explicitly warns that projections which attempt to see more than five years into the future are likely to contain gross inaccuracies.[58] The great German philosopher Kant was even more pessimistic about man's ability to predict the consequences of his acts. Arguing that omniscience would be required to insure accurate prediction, Kant wrote off the entire enterprise of hypothetical ethical analysis and turned his attention instead to the formulation of categorical imperatives.[59] Even if one rejects Kant's extreme position, there remains the question whether ethics or policy should be based solely on a comprehensive assessment of consequences.

This problem can be formulated more precisely with the help of an illustration. Let us assume what Kant would have denied, namely, that in a given case the social consequences of a particular technology could be comprehensively and accurately assessed. One might proceed to record the results of one's analysis on a bar graph as follows:



tions System," *American Journal of International Law* 64 (September, 1970) 163–171; cf. Edward Weisband and Thomas M. Franck, "A Rationale for International Technology Assessment: Towards an Ethical Science," New York University Center for International Studies, Policy Papers, Vol. 4, 1971. The importance of extending TA spatially is already apparent in current discussions of the ocean-pollution problem.

Several questions can be raised about this hypothetical result: (1) How can the various kinds of impacts be compared? Is there a common denominator? (2) Which impact, if any, takes precedence over other possible impacts? Does a negative impact within a particular category, e.g., a negative moral impact, automatically lead to a negative assessment of the technology? (3) How are the various impacts distributed among members of the society? Would a serious negative impact on a few persons be outweighed by a slight positive impact on many persons?[60]

Because of such inherent difficulties in consequential analysis, many moral philosophers and Christian ethicists have suggested that utilitarianism should be supplemented by a second ethical dimension. William Frankena and John Rawls, for example, emphasize the principle of justice or fairness.[61] For Charles Curran, the concept of human dignity serves to limit what may be done, even for the sake of good consequences.[62] Paul Ramsey has repeatedly expressed the view that the Christian ethic is primarily an ethic of means, not of ends.[63] In the theology of Karl Barth, the religious obligation to obey the command of God virtually supplants the duty to calculate consequences.[64]

A final, somewhat more theoretical question can be raised concerning TA: Does the general perspective of TA tend to overlook or obscure certain phenomena of human life? The meaning of this question can be illustrated in two ways. As we have noted, the TA-methodology can be applied either to a particular technology or to a particular social prob-

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[57] On this topic see the following companion essays: Daniel Callahan, "What Obligations Do We Have to Future Generations?" *American Ecclesiastical Review* 164 (1971) 265-80: and M. P. Golding, "Obligations to Future Generations," *Monist* 56 (January, 1972) 85-99.

[58] Committee on Public Engineering Policy, National Academy of Engineering, *A Study of Technology Assessment*, p. 5.

[59] Immanuel Kant, *Groundwork of the Metaphysic of Morals*, tr. H. J. Paton (New York: Harper & Row, 1964) pp. 82-86.

[60] Martin Jones argues that "An unfavorable impact of equal total magnitude... that is concentrated on a few people will cause more social distress than if it were diffused through many people" (see the explanation of the term "Diffusion" on the chart cited in n. 13 above). In order to justify this argument, Jones would have to introduce some nonutilitarian, or nonconsequential, ethical principle. For a discussion of this point, see Frankena, *Ethics*, p. 32.

[61] Frankena, *Ethics*, pp. 38-42; Rawls, *Theory of Justice*, pp. 3-22.

[62] "Theology and Genetics," pp. 83-85.

[63] See, e.g., *Fabricated Man*, pp. 29-30; cf. *Deeds and Rules in Christian Ethics* (New York: Scribner, 1967) pp. 108-9.

[64] *Church Dogmatics* (English tr.) 2/2, 650. Barth accepts the legitimacy of considering consequences but argues that obedience to the divine command is "not merely the highest duty but also the highest good" (*ibid.*, p. 652).

lem. Would the same methodology be applicable to philosophical questions like the following: What goals should we adopt as a nation or an international community? or, What is the end of human life?[65] If the methodology could not address such questions directly, would it allow one's answers to the same questions to affect in a significant way one's over-all assessment of a technology or a problem?

The thrust of this final question can also be illustrated metaphorically. In his book *The Responsible Self*, H. Richard Niebuhr distinguished three images of man: man-the-maker, man-the-citizen, and man-the-answerer. The first image depicts man as a producer of ideas, actions, and things. In the second image, man's duty to obey the civil and moral law predominates. The third image focuses on "man engaged in dialogue, man acting in response to action upon him."[66] It is quite clear that the TA-movement emphasizes the first of these three images, the metaphor of man-the-maker. In so doing, it inevitably tends to neglect other important aspects of human experience.

In summary, the technology-assessment methodology provides a coherent framework for analyzing the social impact of technological change. Although the method was devised primarily in response to environmental problems and developments in the physical sciences, it is in principle applicable to advances in biomedical technology. In fact, several studies of biomedical technology in general, and of genetic technology in particular, have employed analytical categories which parallel precisely the various steps of the TA-methodology.

Because of its intellectual rootage in utilitarianism, the TA-movement tends to focus primary attention on man-the-maker. However, the formal character and inclusive categories of the TA-methodology allow for a significant degree of flexibility in the assessment process. One hopes that in the future this useful analytical tool will be systematically applied to a wide variety of technologies and particularly to the series of complex problems arising in the field of human genetics.

[65] According to Dr. Leon R. Kass, the forthcoming study of the Committee on the Life Sciences and Social Policy will attempt to address precisely such questions.

[66] *The Responsible Self: An Essay in Christian Moral Philosophy* (New York: Harper & Row, 1963) pp. 49–56.