Development of Medical Technology: Opportunities for Assessment

August 1976

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August 16, 1976

The Honorable Harrison A. Williams, Jr.
Chairman
Committee on Labor and Public Welfare
United States Senate
Washington, D.C. 20510

Dear Mr. Chairman:

On behalf of the Office of Technology Assessment, we are pleased to forward a report: Development of Medical Technology: Opportunities for Assessment.

The report was prepared by the Office of Technology Assessment with the assistance of a panel of experts conversant with the development of medical technology and the problems raised by new medical technology. This is in accordance with your request to the Office of Technology Assessment dated February 6, 1975.

This report is being made available to your Committee in accordance with Public Law 92-484.

Sincerely,

Olin E. Teague
Chairman of the Board

Sincerely,

Clifford P. Case
Vice Chairman of the Board

Enclosure

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August 16, 1976

The Honorable Olin E. Teague
Chairman of the Board
Office of Technology Assessment
Congress of the United States
Washington, D. C. 20515

Dear Mr. Chairman:

In response to the request of the Chairman of the Senate Committee on Labor and Public Welfare, I am pleased to submit a report entitled: Development of Medical Technology: Opportunities for Assessment.

The Office of Technology Assessment was assisted in the preparation of this report by an Advisory Panel on Biomedical Research and Medical Technology, chaired by Dr. Eugene A. Stead of the Duke University Medical Center.

The report describes the impacts of medical technology, suggests some questions which could be applied to new medical technologies to assess their impacts, and presents options for a Federal program in medical technology assessment. It is anticipated that the report will be of use to Congressional committees concerned with the Federal role in medical technology development.

Sincerely,

EMILIO Q. DADDARIO
Director

Enclosure

PREFACE

The Office of Technology Assessment (OTA) was asked to examine current Federal policies and existing medical practices to determine whether a reasonable amount of justification should be provided before costly new medical technologies and procedures are put into general use. (Request from the Senate Committee on Labor and Public Welfare on behalf of the Subcommittee on Health, Feb. 6, 1975.) This area of study was endorsed by the OTA Board on April 22, 1975.

This broad issue was discussed by the OTA Health Program Advisory Committee on September 16 and November 3, 1975. Recognizing that the issues related to medical technology are complex, the Advisory Committee recommended dividing the subject into a series of discrete studies. Because it was of interest to Congress, it was decided that the first study should deal with the development of medical technologies. Specifically, the Subcommittee on Health asked OTA to consider—

(1) The need for assessing the social impacts of each new medical technology during the research-and-development process;

(2) The kinds of questions that might be asked in such an assessment; and

(3) By whom and at what point in the research-and-development process assessments could be conducted.

These issues were of particular interest in light of the recent report by the President's Biomedical Research Panel, charged with evaluating biomedical research policy. The OTA report was completed in time to be considered along with the Presidential Panel's findings and other relevant items at oversight hearings on the National Institutes of Health held by the Subcommittee in mid-1976.

This assessment was carried out by staff of the OTA Health Assessment Program with the assistance of the Advisory Panel on Biomedical Research and Medical Technology. This report and the policy alternatives it presents identify a range of viewpoints and do not necessarily reflect the judgment of any individual.

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Chapter I

INTRODUCTION



Chapter I

INTRODUCTION

PURPOSE

In this report, the Office of Technology Assessment (OTA) examines:

- The need for assessing the social impacts of each new medical technology while it is still being developed.
- The kinds of questions that might be asked in such an assessment.
- By whom and at what point in the research and development process assessments could be conducted.

These issues reflect the concern that modest, unexamined investments in biomedical research and development can sometimes lead to large, unexpected costs, both human and financial, in the medical-care system.

The assessment of the potential social impacts of new medical technologies while they are still being developed might serve two important purposes:

- Information obtained from assessments could be used in formulating policies to insure that research-and-development funds are invested wisely. Once the benefits and drawbacks of a particular new technology are considered explicitly, its development might be expedited or constrained, Priority might be given to development of alternative forms of the technology that minimize drawbacks or maximize benefits. One specific issue, for example, concerns whether to invest funds to develop medical technologies that would benefit the greatest number of people, even though such technologies might take many years to develop, or whether to invest those funds in developing technologies in the immediate future that could provide great benefit to (or even save the lives of) relatively few people. Assessment could not, of course, resolve this dilemma, but it might better inform the decisionmaking process that must occur.
- Assessment might provide information that could improve the process of planning for the eventual introduction of new medical technologies into the medical service system. Societal changes that might be required for or result from introduction of a new technology might be anticipated. For example, if programs of medical cost control **are** deemed to be desirable, they could be designed more effectively if information about the nature and potential impacts of new technologies were available before the technologies enter widespread clinical use.

SCOPE OF THE STUDY

This report discusses possibilities for and obstacles to assessing the social impacts of new medical technologies during the stages of research and development that precede their widespread acceptance.

- Technology is defined as "science or knowledge applied to a definite purpose" (86). Thus, medical technology includes all elements of medical practice that are knowledge-based, including hardware (e.g., equipment and facilities) and software (e.g., knowledge and skills) (83, p. 31; 166). Medical technology is defined as the set of techniques, drugs, equipment, and procedures used by health-care professionals in delivering medical care to individuals and the systems within which such care is delivered.
- The social impacts of new technologies can be assessed in a variety of ways. Technology *Assessment* is a form of policy research that purports to provide a systematic and comprehensive format for considering the broad implications of introducing a new technology. Effective assessment may also be accomplished in administrative, public, or academic forums, however, by methods that do not fit the definition of technology assessment.
- The term research and *development* refers to a variety of activities whose purpose is to acquire knowledge and then to apply it to the creation of clinically useful medical technologies. These activities include basic research, applied research, targeted technology development, initial human use, clinical testing, and early stages of experimental clinical practice.

There are five principal boundaries on the scope of this study. The first concerns the types of medical technology. Medical technologies are used for five different purposes: prevention, diagnosis, treatment, support, and administration. Technologies of the latter two classes are not discussed in this report. Similarly, many technologies that may have great impact on health but that do not fit within this definition such as food-producing technology or technology for improving the environment are excluded from consideration in this report.

A second boundary on the scope of this study is in the kinds of concerns addressed. Medical technologies pose both technical and social problems, but only the latter are considered here. Methods for assessing technical factors, such as safety and efficacy, will be examined in a subsequent report from OTA.

A third boundary is that the study focuses on research and development but does not examine ways to assess technologies that are already in use. This is an important limitation because many of the problems posed by the use of medical technology can be addressed only by assessing the system of health-care delivery within which they are used.

A fourth boundary is that the study describes ways to assess the impacts of medical technologies while they are still being developed, but does not consider how one might evaluate the social utility of biomedical research, per se, or of particular programs of research. Research aimed at the generation of new knowledge and unrelated to the development of new technologies could not be assessed by the methods described in this report.

The fifth boundary concerns proposals for implementing technology assessment. Although the report discusses biomedical research and technology development in broad terms, and presents a general framework for assessment, the policy options refer only to Federal agencies.

Note.—Figures in parentheses indicate reference sources in Bibliography.

ORGANIZATION OF THIS REPORT

Chapter II points out both the need for and the difficulty of assessing the social impacts of new medical technologies. Nine short case histories are used to illustrate the diverse nature of medical technologies, the complexity of technology development, and the variety of problems that technologies pose. (A more detailed and systematic description of how medical technologies are developed is presented in app. A.)

Chapter 111 discusses the types of impacts of new medical technologies that need to be assessed. These impacts may result either from the economic burdens imposed by widespread use of a new technology or from indirect benefits and drawbacks of the technology itself. The chapter contains a list of questions that might be used to elicit information about the impacts of new medical technologies on the individual (patient), on families and populations, and on social, medical, economic, legal, and political systems.

Chapter IV describes a method, technology assessment, that can be used to identify and evaluate the potential impacts of introducing a new technology. The strengths and limitations of this method are discussed, and some alternate modes of assessment are presented. This chapter also considers criteria for selecting medical technologies to assess, steps in conducting a medical technology assessment, and ways in which the results of medical technology assessments might be used.

Chapter V summarizes the possibilities for and limitations of social-impact assessment and then presents policy alternatives for implementing programs of technology assessment at Federal agencies such as the National Institutes of Health (NIH) that develop or support the development of new medical technologies.

DEVELOPMENTS IN MEDICAL TECHNOLOGY



This artificial heart kept a calf alive for a record 1451/2 days. The inflow valve of the right heart is removed to show the dark surface of the rubber diaphragm.



Nuclear-powered cardiac pacemaker (left) and heart electrode. The electrode normally is in contact with the left ventricle of the heart.



This renal dialysis machine purifies blood through an artificial kidney.

Photos COURTESY Cleveland Clinic, NIH

Chapter II

WHAT IS MEDICAL TECHNOLOGY AND WHY SHOULD IT BE ASSESSED?



Chapter II

WHAT IS MEDICAL TECHNOLOGY AND WHY SHOULD IT BE ASSESSED?

New medical technologies have transformed medical practice in the past several decades by making effective preventive, diagnostic, and therapeutic tools available to the medical-care system (3). Some diseases can now be effectively prevented, and medical innovations such as antibiotics have provided effective therapies for a number of other diseases. New diagnostic techniques have frequently made it possible to detect disease in time to apply an appropriate therapy. Even in cases of diseases for which no effective preventive or therapeutic measures are available, relief of pain, amelioration of symptoms, and rehabilitation of individuals affected by chronic conditions have been increasingly feasible.

On the other hand, the accelerating pace of medical technology development has raised a number of troubling issues. Questions are being asked about whether current R&D efforts are directed at developing the most desirable technologies, whether adequate planning precedes the introduction of new technologies into the medical-care delivery system, and whether the introduction of some new medical technologies may have indirect or unanticipated social implications.

One way to address these issues might be to assess the social impacts of new medical technologies while they are still being developed. To begin the discussion of this possibility, this chapter describes the aims, nature, development, and clinical status of nine medical technologies.[1] These nine cases are designed to show what medical technologies are, how they are developed, and why it might be profitable to assess their social impacts. In addition, the cases and the overview that follows them point out some of the complexities that will have to be recognized if medical technologies are to be effectively assessed:

- Medical technologies are extraordinarily diverse in nature and are used for a wide variety of purposes.
- Medical technologies are devised in a great variety of ways and places.
- The development and use of medical technologies pose a large number of problems, including some that are purely technical (or medical) and others that involve wider social issues.
- Technical and social problems often cannot easily be separated; they are inextricably linked.

[1] The nine technologies described here were chosen by the Advisory Panel to this study because they illustrate a variety of technological solutions to medical problems and because they raise a broad array of important issues, These cases do not, however, purport to illustrate all of the important aspects of medical technology that must be considered in implementing programs of assessment, nor can the points illustrated here be generalized to all other cases.

1. The Continuous Flow-Blood Analyzer[2]

The primary function of the clinical laboratory is to analyze and provide data on samples of body tissues or fluids. After correlating these data with firsthand observations and results of other tests, physicians are better able to make accurate diagnoses and to determine the proper therapy for their patients. Reliable data from clinical laboratories is essential for current medical practice (143).

Clinical laboratories perform a wide variety of tests. Because some tests on blood are fairly simple, proceed according to a standard protocol, and yield easily quantified results, it has been possible to automate them. The advantages of automated testing include both increased precision and decreased unit cost (5, 154). A number of machines have been introduced to achieve automation of blood testing; perhaps the most widely adopted is the continuous flow-blood chemistry analyzer.

The continuous flow-blood analyzer was invented by Leonard Skeggs in 1950. His device removed protein from the serum, added test reagents to small amounts of the remaining sample, incubated the mixture, measured the rate of the test reaction, and drew a curve indicating the results. These curves could then be readily interpreted to indicate the amounts of certain chemicals (such as glucose or blood urea nitrogen) that were in the blood samples.

The tests are based on chemical and biochemical principles that have been derived from basic research and applied to clinical problems over a period of many years. Skeggs' contribution was to develop ingenious methods for automating the routine, iterative steps of the testing protocol.

Skeggs built a prototype machine in his basement for about $1,500, completing it in 1951. Between 1951 and 1954, he attempted to interest private companies in the machine. The Technicon Corp. signed a contract with Skeggs in 1954 and was assigned his patents. From 1954 to 1957, Technicon improved and modified the design at a cost of about $1 million and finally made a production model. By the end of 1957, Technicon had sold 50 systems for about $5,000 each. In 1961, Skeggs designed a new machine that performed multiple tests on a single sample of blood and reported the several results together. This new machine was tested in 1963, soon marketed, and readily accepted.

Subsequent models have improved the original design and permitted increasing numbers of tests to be done on a single sample. These new machines have been increasingly costly to develop and to manufacture. In 1973, for example, a machine that could perform up to 20 tests (the Sequential Multiple-Analyzer with Computer (SMAC)) was introduced. The cost of developing the SMAC was almost $7 million and each machine now sells for $250,000.

By adopting machines such as the continuous flow-blood chemistry analyzers, many hospitals and independent testing firms have automated their clinical laboratories during the past decade (5). Technicon sold about 18,000 analyzers by 1969, and by 1974 another 8,000 of a newer model, introduced in 1970, had been

[2]Most of the material in this case that is not otherwise referenced is drawn from ref. 117.

sold. By 1972, more than 50 percent of hospitals had automated their chemistry and/or hematology laboratories, and almost 50 percent of independent laboratories had automated one or both functions. Both operations had been automated in essentially all of the larger laboratories and hospital.

The fiscal impact of laboratory testing is profound. In 1971, an estimated 2.9 billion tests were done at a cost of $5.6 billion (218). The costs rose to over $11 billion by 1974 and were estimated to be $15 billion in 1975 (21), more than 10 percent of the total national health expenditure. The number of tests reached 5 billion in **1975** and is projected to rise at a rate of 11 percent per year for the foreseeable future (218).

Although large machines such as blood chemistry analyzers dramatically symbolize the huge expenses involved in clinical laboratory testing, the cost of the equipment itself is relatively small. Expenditures for laboratory instruments of all types in the United States reached $220 million in 1974 (115), but this was only 21/z percent of the clinical laboratory bill. The expense of clinical laboratory testing is made up primarily by investment in space, supplies, and maintenance; personnel costs for carrying out the procedures and collecting, recording, and reporting the results; and profits of the laboratories and the physician. Thus, relatively modest expenditures for equipment can lead to enormous costs for the medical-care system.

An additional cost, which is much more difficult to measure, stems from the increased use of laboratory testing that may have been stimulated by the ready availability of automated equipment (154). In particular, the multichannel analyzers described above make it possible to perform many "extra" tests on a single sample, at low unit but high aggregate cost. The growth of third-party payment mechanisms may also have provided some impetus for the increased use of clinical laboratories. Furthermore, as such testing has become increasingly used, fears of malpractice liability may have led to requests for even more tests, as part of the practice that has been called "defensive medicine." Some have suggested that many more clinical tests are now performed than are necessary for even the most rigorous medical practice *(176, 177),* and a study indicated that doctors frequently fail to use the results of tests that they have ordered (215).

This case illustrates two important points about the development and use of medical technologies. First, although the principles of clinical laboratory testing are based on knowledge derived from biochemical research, which is largely Government funded, the automated analyzers now used were developed almost entirely by private industry. Second, the bulk of high clinical laboratory costs are not due directly to the high cost of the machinery, but rather are due to the cost of supplies and personnel that the machines require, to substantial profits by laboratory owners and physicians, and to increased (possibly excessive) demand for testing that their availability has stimulated.

2. The Computerized Axial Tomography (CAT) Scanners

The computerized axial tomography (CAT) scanner, which combines sophisticated X-ray equipment with an on-line computer, has **been** hailed as the

[3] The historical material in this case is drawn from ref. 11, pp. K1–K8.

greatest advance in radiology since the field was created by the discovery of X-rays. The X-ray unit directs beams of X-rays through the human body from multiple directions, and the computer analyzes the information thus obtained to reconstruct images of cross-sectional planes that could not be visualized by conventional radiological techniques. The CAT scanner has revolutionized diagnosis of abnormalities within the skull, such as brain tumors, and is already being used widely.

The development of the scanner resulted from research in mathematics, radiology, and computer technology. Research at the beginning of this century provided a mathematical basis for image reconstruction, but the procedures were laborious and awaited the availability of computer methods for their complete development. Meanwhile, research in radiology provided sophisticated new techniques. Oldendorf and Cormack built crude scanning devices in the United States in the early 1960's, reporting their work primarily in the technical literature of applied physics. It was difficult to obtain funding for further work, because Government agencies such as NIH did not perceive its potential, and private companies felt that the costs of solving the engineering and computing problems that remained would exceed any potential profit.

Hounsfield, working in the research laboratories of a British electronics firm called EMI, Ltd., began to work on the same concept in 1967 and obtained a British patent in 1969. His company was also initially unwilling to assume the financial risk of developing a clinically useful device, but the British Government granted funds for developing four prototypes. A workable scanner was ready by 1971 and was first used clinically by Ambrose in England. The first unit in the United States was installed at the Mayo Clinic in 1973.

The scanner was immediately successful, and several firms quickly developed and marketed similar models. At present, there are more than 300 scanners in use in the United States, and several hundred more have been ordered. Each scanner costs from $350,000 to $700,000. These machines are used to detect abnormalities in the head; new scanners that extend tomographic capability to the whole body have recently been developed and are now being marketed.

The expenditure for CAT scanning is already enormous. Currently, more than $200 is charged Per scan, and a recent nationwide studv showed that each machine is used to scan "approximately 12 patients per day (100). Thus, with over 300 machines in use, the yearly bill for scanning may approach $200 million.

The CAT scanner is unquestionably a major technological advance, but its impact on the health of patients has not yet been carefully evaluated. Studies done so far indicate that CAT scanning does tend to replace pneumoencephalography, an invasive and painful diagnostic procedure (100). Many more scans are now done, however, than can be accounted for by substitution for previously available techniques. CAT scanning provides physicians with a wealth of diagnostic information that would not otherwise be available, but the extent to which this additional information can be used profitably to design programs of therapy is not known. Recent controversy has centered on the question of whether more scanners are being purchased and used than are necessary to insure an optimal level of medical care for neurologically disabled patients (214).

This case of the CAT scanner, a newly developed diagnostic device, raises three points that assessors of technology development must consider. First,

although much of the basis for the scanner was provided by research done in the United States, targeted development was not supported in this country, and the first clinically useful device was manufactured in England. Decisions made at the National Institutes of Health or other U.S. agencies may have a limited effect on the progress of R&D in other countries. Second, private companies were initially unwilling to invest in developing the scanner because they did not think it would be profitable. A (British) Government procurement program may have helped to overcome this barrier. Such collaborations between Government and industry may provide a mechanism for expediting the development of useful but costly technologies. Finally, although it was introduced only 3 years ago, the scanner has already been widely adopted and has had a profound effect on the medical economy. The scanner's technical advantages and value as a tool for diagnosis and clinical research are indisputable, but the effect of its use on the health of patients has not yet been carefully evaluated. Assessment of technologies like the CAT scanner might be directed at the patterns of their utilization as well as at their development or technical status.

3. Polio and Rubella Vaccines[4]

The objective of immunization is to prevent disease. Successful vaccines produce, without harm to the recipient, a degree of immunity which approaches that following a disabling attack of a natural infection. The human body has an immune system that can attack and destroy invading agents such as disease-causing bacteria or viruses. A vaccine is a preparation of inactivated or weakened bacterial or viral material that stimulates the immune system without itself causing serious disease. If infectious agents then invade the body, the immune system is prepared to attack; thus, the disease is prevented (163).

Jenner is considered to be the father of immunization. He observed that those infected naturally with cowpox did not subsequently contract smallpox. In 1796, he began using material from cows infected with cowpox as an agent for vaccinating people, thereby preventing smallpox. In the late 1800's, Pasteur discovered that infectious material (later shown to be viruses) from rabid animals could be treated to reduce its virulence. He used such treated material to vaccinate a boy who had been bitten by a rabid dog; the boy survived. Pasteur's use of a modified infectious agent to prepare a vaccine represents the beginning of modern preventive immunization (163). During the subsequent decades, vaccines were developed against a variety of diseases, including diphtheria, pertussis, and tetanus.

By *preventing* disease rather than treating its symptoms, vaccines have been able to avert much suffering and save many lives. Additionally, immunization programs have been quite cost saving for society. They not only save in the costs of medical care for the affected individual but also keep citizens productive for themselves, their families, and the entire society. Occasionally, vaccination may have undesirable side effects. Nevertheless, vaccines are the model preventive technique and are often used to illustrate the argument that knowledge gained from basic biomedical research can lead to conquest and nearly complete eradication of disease.

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[4] This case is adapted from material prepared for OTA by Dr. Joseph Melnick, a member of the Advisory Panel for this study.

POLIO

The prevention of poliomyelitis by immunization is a modern success story. Faced with poliomyelitis epidemics of great severity after World War I, the public regarded this disease with dread. Thousands died or were permanently crippled by extensive paralysis; even very costly and uncomfortable therapy often led only to partial rehabilitation. The specter of poliomyelitis gadgetry such as the "iron lung" still lingers in the public mind today.

This terrifying image of polio motivated the creation, in 1938, of the National Foundation for Infantile Paralysis. The Foundation sponsored the first large program of directed, interuniversity cooperative medical research and development in the United States. Under its auspices, diverse lines of exploratory research were pulled together toward the common goal of preventing or curing poliomyelitis. The public felt that the research effort was a legitimate path to this goal and gave its wholehearted support: contributions reached $20 million per year by the early 1940's and continued for two decades.

The development of successful polio vaccines followed a long history of research on immunization, viruses, and the nature of polio. Poliomyelitis was first recognized as a clinical entity in the late-18th century. In the early-20th century the. disease was successfully transmitted to laboratory animals and shown to be caused by a virus. These developments made possible experimental work on polio virus and an increased understanding of the disease. This research culminated in the cultivation of the virus in cell cultures by Enders, Weller, and Robbins in 1949 (62), providing a large-scale source of virus from which vaccines could be made. Based on the knowledge gained from immunization programs for other diseases, a polio vaccine was soon developed and tested in animals. Successful immunization of human subjects with killed virus was reported by Salk (174) in 1953 and nationwide field trials were carried out in 1954. The vaccine was licensed in 1955, and widespread administration began almost immediately. In the meantime, attenuated live virus vaccines were being developed, and the Sabin strains of such vaccines were licensed in 1961, following extensive field trials.

Results of large-scale immunization programs, using Salk and later Sabin vaccines, have been extraordinary: 18,000 cases of paralytic polio were reported in the United States in 1954, 2,500 cases in 1960, and only 6 cases in 1975 (79). The human, societal, and economic benefits have been enormous: a huge and costly program of rehabilitation has been dismantled, billions of dollars have been gained from increased productivity (210), thousands of lives have been saved, and incalculable suffering has been averted. Recently, however, the level of immunization among children has fallen off (118, 131), and there is some possibility of increased incidence of polio in the future.

RUBELLA

Rubella (German measles) briefly incapacitates its victims and occasionally leads to serious complications, but is rarely crippling or fatal. In 1941, however, Gregg discovered that pregnant women who contracted rubella had a greatly increased risk of giving birth to children with devastating congenital defects, including severe mental retardation. Other impacts of rubella are illustrated by the epidemic of 1964–65, which was estimated to have a direct cost (e.g., medical care for the ill and for congenitally damaged offspring) of more than $1 billion and indirect costs (e.g., lost productivity) of more than half a billion dollars (179). At least

20,000 congenitally infected "rubella babies" were born with abnormalities as a result of this epidemic, and there were as many as 30,000 fetal deaths due to maternal infection with the virus.

The technology gained in the development of poliovirus vaccines has been effectively applied to rubella. In 1961, rubella virus was grown in tissue culture and methods for measuring an immune response to the virus were developed (161, 21 1). Parkman, Meyer, and their colleagues at NIH developed an attenuated live rubella virus in 1966, and, in the same year, reported its experimental administration as a vaccine to children (132). After further trials, the vaccine was licensed in 1969. Another attenuated virus strain was developed in Belgium by Huygelen, Peetermans, and Prinzie (96) and was also licensed in 1969. A third vaccine strain developed in the United States without Federal funding was not licensed.

By 1974, 62 percent of the target population (children aged 1 to 12 years) had been vaccinated against rubella. In 1975, 16,343 cases were reported, a 66-percent decrease from a yearly average of 47,744 cases during the period preceding widespread use of the vaccine. Thus, an effective vaccine has been developed, but has not yet been adequately applied to provide optimal protection (175). There remains a risk to those not receiving the vaccine and a lack of overall protection that more widespread immunization could furnish.

The vaccine cases illustrate two interesting points. First, basic research has led to the rational development of technologies that can prevent disease and render less rationally designed, relatively ineffective, and costly treatments essentially obsolete. Second, even after such inexpensive and effective technologies are developed, they may not be universally used. The enormous human, social, and economic costs of this incomplete protection are due not to any failure in research or development, but to shortcomings in the medical-care delivery system.

4. Radical Mastectomy for Breast Cancer

Breast cancer (carcinoma of the breast) is the major fatal cancer among American women. It attacks 6 percent of women and kills half of its victims (38). In 1974 there were an estimated 89,000 new cases and 32,500 deaths from breast cancer in the United States. Epidemiological and biomedical studies have implicated genetic, environmental, hormonal, and viral factors in the etiology of breast cancer. No firm evidence is yet available, however, and the cause of the disease remains unknown.

Radical mastectomy was introduced as a treatment for breast cancer by Halsted, a pioneer of American surgery, in 1890. It involves removal of the breast, the underlying pectoral muscles, and the axillary (armpit) lymph nodes. The rationale for removing large amounts of tissue is that breast cancers spread rapidly and have often invaded nearby areas by the time of diagnosis and surgery. Radical mastectomy is a mutilating procedure and causes significant psychological and social as well as physical problems (170). Nevertheless, it was long the only form of therapy known and has remained the orthodox treatment for breast cancer since its introduction.

During the past few decades, several alternatives to radical mastectomy have been introduced. A surgical variant, simple mastectomy, entails removal of the

breast but not the underlying muscle and lymph nodes. Radiotherapy has been administered from external devices (25) and from implanted isotopic pellets, either alone or in conjunction with surgery. Similarly, a variety of anticancer drugs have been used in chemotherapy programs (18), either following mastectomy or as a primary treatment. Considerable success has been achieved with several of these procedures. No treatment devised so far, however, including radical mastectomy, is completely effective in preventing the recurrence of breast cancer or its spread to other parts of the body.

Despite the severity of radical mastectomy, its incomplete success, and the availability of other forms of treatment, few rigorous comparisons of alternate therapies have been attempted. Physicians have considered it unethical or inadvisable to withhold radical mastectomy, an accepted, partially effective procedure, from patients whose lives were threatened. Some studies were done, however, both in the United States and in Great Britain, and their results suggested that several forms of treatment are equally effective (22). In 1971, NIH initiated a controlled clinical trial under the direction of Dr. Bernard Fisher (66) at the University of Pittsburgh. Surgeons, radiotherapists, and pathologists in 34 institutions are attempting to compare the efficacy of alternate therapies for breast cancer. Patients have been divided into three groups and submitted to radical mastectomy, simple mastectomy, or simple mastectomy plus radiation therapy. The study involves 1,700 patients. The preliminary results indicate that the survival rates of patients in all three groups are essentially equivalent (153). These initial findings have already raised some doubt about the necessity for widespread use of radical mastectomy. However, firm conclusions cannot be drawn until the study is completed.

This case points out that a mutilating surgical procedure can be widely used without proof that it is more effective than alternatives that cause less physical and psychological damage. To seek this proof, an accepted procedure has been withheld from patients, and this is ethically troubling to many physicians. As new and potentially more effective therapies are developed, such ethical problems may again have to be confronted.

5. **Anticoagulants for Acute Myocardial Infarctions**

An "acute myocardial infarction," or heart attack, results from destruction of heart tissue following blockage of a coronary artery by atherosclerosis (deposition of fat in the arteries). Coronary heart disease leads all causes of death among the middle-aged and elderly, striking males two to five times as often as females (33).

A variety of therapies have been developed to deal with various clinical problems that follow acute myocardial infarction. One therapy that has been widely used is the administration of drugs called anticoagulants, which inhibit the reactions that cause blood to clot at the site of an injury. It was hoped that these drugs could prevent blood clots from forming on the damaged heart wall or in the partially blocked coronary arteries.

The potential value of anticoagulants in the treatment of myocardial infarction was demonstrated in research on dogs in 1939. Development of blood clots in an experimentally damaged heart was prevented by injection of the anticoagulant heparin. Because of high costs and problems of chronic administration, however, .

[5] The historical material in this case is drawn from ref. 60.

extensive human use was not feasible. In 1946, dicoumarol, an anticoagulant that could readily be administered orally, was discovered. This drug was administered to a number of patients, and the results of early experience were promising.

In 1948 a large-scale controlled clinical trial of long-term dicoumarol therapy was started in the United States. This was one of the first such clinical trials. A striking reduction in mortality was reported in the group receiving anticoagulants, and the treatment was rapidly and widely adopted.

During the subsequent several years, however, four smaller clinical trials of dicoumarol showed no significant difference in mortality between treated and control groups. It was belatedly realized that the method used in the first trial to assign patients to control and treated groups had been flawed. Patients admitted to cooperating hospitals on odd days were all given anticoagulants, while those entering on even days were assigned to the control group. Physicians, knowing this protocol, were aware of which patients were being treated. This knowledge could have affected their behavior, or even allowed them to admit "promising" patients on an appropriate day, thus affecting the results of the trial. To resolve the question, a new large-scale clinical trial was organized in Britain. Its results showed that there was no significant, long-term effect of dicoumarol on mortality following myocardial infarction.

In retrospect, it was realized that anticoagulants could be expected to prevent only some of the complications that follow acute myocardial infarction (in particular, "thromboembolic complications," involving clotting of the blood), and thus could lower mortality by only 2 or 3 percent even if completely effective. This recognition led to a large collaborative study in Veterans Administration hospitals focusing on thromboembolic complications, including strokes. The incidence of stroke in the untreated group was 3.8 percent compared with 0.8 percent in the treated groups (58). This difference was judged to be a benefit of anticoagulant therapy during a short period following infarction. However, long-term administration of anticoagulants was again found to have no discernible benefit (59).

Thus anticoagulation was rapidly accepted as a treatment based on what at the time seemed like rigorous evidence of efficacy. Many patients remained on the drug for years and were exposed to the real, albeit low, risk of harmful side effects. Only later were the inefficacy of long-term therapy and the possible usefulness of short-term therapy demonstrated (40).

This case points out that the results of evaluation, on which decisions must be based, may be misleading. Even with the best possible evaluation, based on the state of the art of the day, mistakes will be made. Because of this possibility for error, continuing surveillance of technology is necessary to identify ineffective or unsafe procedures after some period of use.

6. Renal Dialysis[6]

The kidneys filter or "dialyze" the blood to maintain the delicate chemical balance of the human body. If the kidneys are diseased and do not remove wastes from the blood, uremia—urea in the blood-develops.

[6]The historical material in this case is drawn from ref. 69, pp. 215–239.

The severity of uremia parallels the extent of kidney failure. The permanent loss of function of both kidneys, called chronic renal failure, is invariably fatal if untreated. In such cases, a dialysis machine, or "artificial kidney, " can remove the wastes from the blood, preventing death and often allowing the affected individual to function normally.

The first dialysis machine was built by Dr. Willem Kolff in Holland in the early 1940's from an old bathtub, spare automobile parts, and sausage casings. By 1950, several American medical centers were using experimental models. During this time, sustained therapy was limited by the fact that each time a patient was dialyzed, he or she had to undergo surgery to insert cannulas (tubes) into an artery and a vein. The main use of the early machines was to maintain patients during periods of acute short-term renal failure. As late as 1960, the longest reported maintenance of a patient on a machine was 181 days.

Long-term dialysis for chronic renal failure became possible in 1960 when Scribner and his colleagues developed a semipermanent apparatus that linked an artery to a vein. This device, the "Scribner shunt, " could be used to connect patient and machine, without surgery, for each session of dialysis. The shunt worked from the beginning: the first three patients treated by Dr. Scribner with the "Scribner shunt" were still alive for a reception in their honor in 1970.

The development of the shunt made dialysis possible for individuals with chronic renal failure. As an early analysis concluded, this was a sizable group:

> In considering the impact of kidney diseases we find that between July 1964 and June 1965 there were 58,788 deaths, a prevalence of 7,847,000 cases, 139,939,000 days of restricted activity . . . . Likewise in 1964 the total economic cost of kidney disease was $3,635,000,000. 'The indirect costs of morbidity and mortality accounted for $2,000, -412,000 of the total cost with the larger portion due to morbidity loss (81, p. 1).

It was not immediately possible to treat all eligible patients, however, because of shortages of dialysis machines and qualified facilities. A clinical center for hemodialysis was opened in Seattle with support from a 3-year grant of $250,000 from a private foundation. The center opened on January 1, 1962, and was immediately inundated with candidates for long-term hemodialysis. However, when the first grant ended, it was not renewed. NIH funds, which had supported research on dialysis, were not available for treatment. The center in Seattle, as well as others that were established, encountered serious financial problems.

Furthermore, dialysis is very expensive. The equipment itself is costly, but far more important is the fact that each patient must undergo two or three 6- to 8-hour sessions of dialysis each week in order to avoid uremia and its fatal outcome. Once a patient starts on hemodialysis, he or she may be able to return to normal functioning, but he or she cannot survive without dialysis unless kidney transplantation is possible and successful. The cost of dialysis ranges from about $30,000 per year for in-hospital dialysis to about $4,500 per year for dialysis carried out in the patient's home, after an initial expenditure of $3,000 for equipment and home alterations (106, p. 12). The need for sustained use of the "artificial kidney" imposes a tremendous financial burden on the patient.

These financial problems were addressed by Congress in the Social Security Amendments of 1973 (Public Law 92-603), which expands Medicare coverage to include all patients with endstage renal disease, whatever their age or financial status. This program provided care for 21,500 eligible patients in 1976, at a cost of $448 million. The cost of this program is expected to reach $1 billion by 1984 for the treatment of more than 50,000 patients. Some believe that the program will cost $1.7 billion by 1990, with up to 70,000 patients involved (205).

The early success of dialysis raised many difficult issues centering around the allocation of scarce medical resources. The cost of treatment was high, and machines were few. Very quickly, selection of patients for the limited number of machines available became the most difficult issue. The passage of Public Law 92-603 addressed some of these problems but created new ones. First, the Federal program unquestionably saves lives, but it is very expensive. Some have suggested that the money would be better spent on programs of preventive or community health that would benefit more people or on research, which holds the potential for leading to more definitive cures. Such programs of "catastrophic disease insurance" raise questions about national priorities (98). Second, now that Federal funds are available, dialysis is increasingly being used as part of a "life-support" system for terminally ill patients, raising questions about the provision of expensive care for patients who have little or no hope of recovery (48).

7. The Cardiac Pacemaker

The pathological condition ameliorated by the artificial pacemaker is heart block or Stokes-Adams syndrome. The electrical signal that triggers the heartbeat arises in a particular region of the heart and is transmitted through a cellular conduction pathway to stimulate the coordinated contraction of the heart. In heart block, signals are not properly conducted, resulting in abnormal heart function and circulatory insufficiency (188). The pacemaker provides a regular sequence of impulses to the heart, causing it to operate normally. The results are dramatic. The mortality rate in unpaced patients with severe heart block is about 50 percent over a l-year period, whereas the life expectancy of an artificially paced patient suffering from the disease is over 90 percent of that of the normal population of comparable age and sex. With an artificial pacemaker, those afflicted lead normal lives,

The pacemaker is an example of an advance that could not be made until knowledge in several related fields was ripe for it. As early as 1791 it was observed that the heart of a frog could be stimulated with electrical energy. Similar demonstrations were made on the human heart during the 18th and 19th centuries. In 1932, Hyman demonstrated that it was possible to stimulate the human heart by electrical impulses delivered by a needle electrode inserted through the chest wall into the heart. However, Hyman did not publish his resuIts at that time, possibIy because of opposition to his work in the medical and lay communities. Many people objected to his device as tampering with Divine Providence. Also, Hyman was

p The historical material in this case is drawn from refs. 11 (pp. J1–J11) and 12.

unable to find an American manufacturer who was willing to produce his device. World War II diverted his efforts, and, he did not pursue this research.

During the war, extraordinary technical advances in instrumentation and electronics occurred. Cardiac and thoracic surgery also developed rapidly. Bigelow and his associates in Canada experimented with pacing the heart after open-heart surgery. In 1952, Zoll reported that heart block could be treated by electrical impulses delivered to the chest wall. However, this mode of stimulation was too cumbersome and uncomfortable to the patient to be practical for sustained use. Lillehei and coworkers in the United States took a step toward solving these problems by developing a system with internal electrodes and a portable external power supply. Their pacemaker was first used in 1957.

Progress in electrode and battery technology soon made it clear that long-term pacing should be feasible. In 1958, Elmquist and Senning developed a totally implantable system with its own power source, a rechargeable nickel-cadmium battery. They implanted this pacemaker in a patient, but the electrodes did not work well. Finally, Chardack and Greatbatch, combining an improved lead devised by Hunter and Roth with new mercury cell batteries and a transistorized circuit, implanted a system in 1960. This device was very successful and, with a few modifications, was manufactured and marketed by Medtronic, Inc.

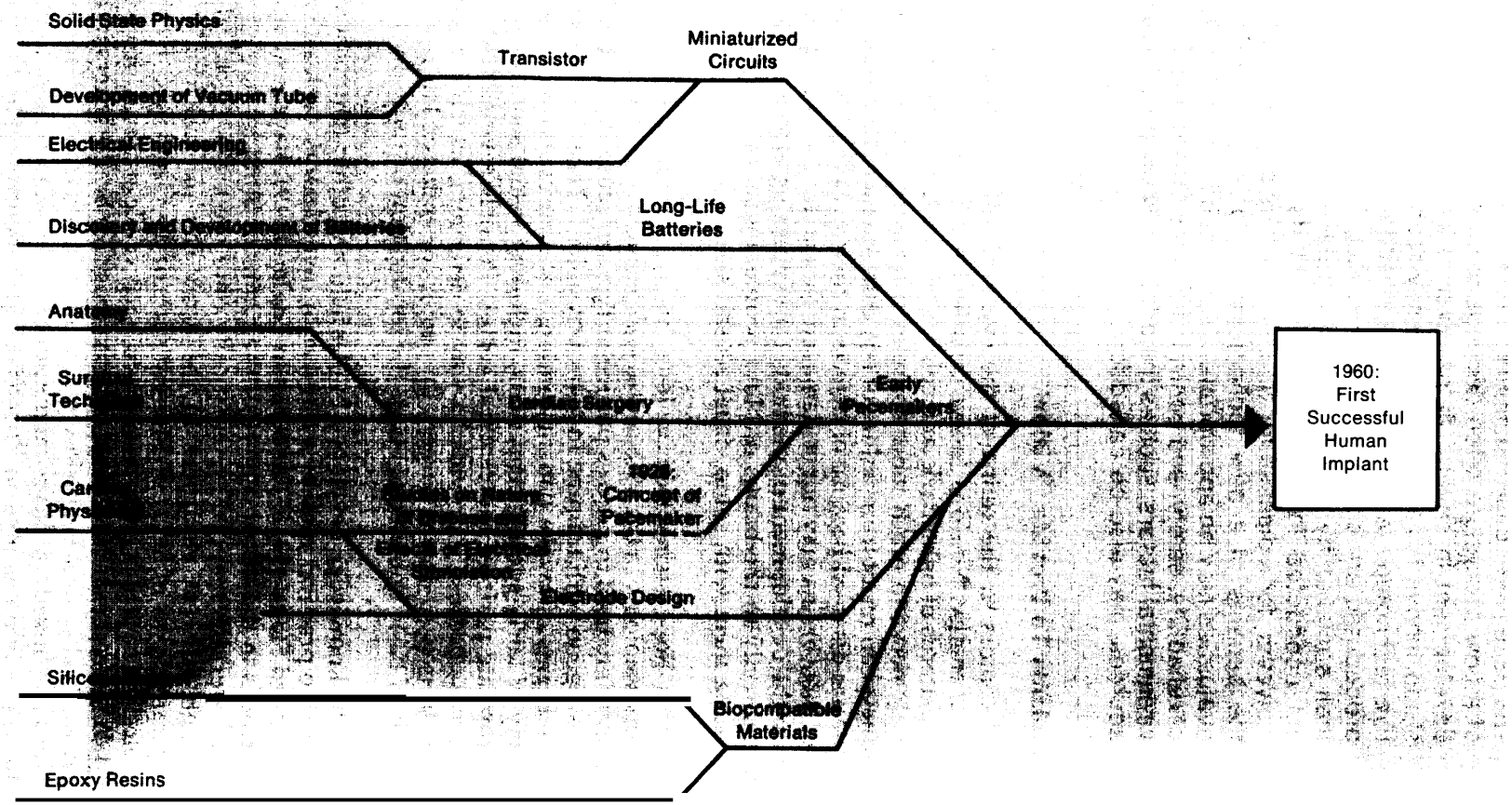
Thus, the totally implantable pacemaker required the development of basic knowledge about the physiology and electrical conduction system of the heart before it could be used. In addition, technological developments in batteries and electrodes were necessary. Materials to insulate the pacemaker and the body from each other were also necessary; epoxies and silicone rubber proved effective. Finally, innovative proven surgical techniques were required to enable implantation of the device. The confluence of these several lines of research and development to produce a clinically useful device is shown in figure 1.

Little Government funding for the research and development of the pacemaker **was** forthcoming until the latter stages. Zoll had Government help, and the practical work from that point was partially supported by Federal funds. Major development was carried on with private resources of Medtronic, Inc., and other companies that subsequently marketed models. The pacemaker is the result of a creative effort financed by both public and private sources,

Once developed, pacemakers were received as a genuine technological triumph and were widely accepted by the medical community. Use of pacemakers has increased each year since 1960 (see fig, 3D in app. A). About 75,000 units were sold in the United States during 1975, with worldwide sales estimated at 147,000 units. The world pacemaker business now grosses approximately $200 million a year.

CurrentIy, a principal limitation of pacemakers is the finite life of their batteries. Although unexpected failures are extremely rare, each patient requires periodic minor surgery for replacement of the unit. New power sources such as lithium cells might extend battery life to approximately 10 years. Nuclear-powered pacemakers may also alleviate this constraint and are presently undergoing clinical trials. Work on other types of energy sources, such as bioelectric fuel cells, is also proceeding, but at a relatively slow rate. Some are concerned that nuclear-powered pacemakers may expose the patient or others to radiation. The benefits and drawbacks of alternative power sources are currently being debated.

Figure 1—**Development the Cardiac Pacemaker**



The pacemaker case highlights several important points. First, development of a new procedure often depends upon a background of knowledge and development in several fields. Even if fundamental principles are understood, innovation and application may not be feasible until pertinent supportive technology is ready. Second, despite their complexity and cost, some procedures are so effective in restoring function that few would question their social utility. Third, a rigorous controlled clinical trial apparently was not conducted for the pacemaker in its early stages of development. However, for a disease for which the natural history is fairly well known and the benefits of a new technology are dramatic, alternative methods of evaluation may be appropriate. Such methods should include consideration of reliability, safety, and contraindications. Assessment of societal and environmental factors, such as the effects of widespread use of nuclear power sources, may also be called for.

8. Cortical Implants To Provide "Vision"

Receptors in the retina of the eye sense light and convert light energy to " electrical energy. Neurons (nerve cells) in the retina begin to analyze information about patterns of light, dark, and color, and then transmit electrical signals through the optic nerve to much more complex processing centers in the brain. Although blindness can result from failure of any component of the visual system, most blind people are disabled because of defects in their eyes or optic nerves, the visual centers of their brains may not be damaged. Research now in progress (19, 52, 53) may lead to the development of methods for connecting electronic light-sensing equipment directly to the brains of blind people, bypassing their failed eyes, and thus providing them with some visual sensation.

This hope stems from a long history of research in neuroanatomy and neurophysiology, In the 19th century, experiments showed that specific portions of the brain are used to process particular types of sensation. In the 1930's, Penfield, a neurosurgeon with training in neurophysiology, began using electrical stimulation of the brains of awake patients undergoing neurosurgery. He was able to elicit a variety of fairly specific sensations, including visual sensations, by stimulation of appropriate parts of the cerebral cortex. Penfield's work had immediate clinical usefulness because it provided a way to determine which areas of the brain could safely be excised during surgery for tumors or epilepsy. His results also provided a wealth of basic knowledge about the localization of function in the brain.

The knowledge developed by Penfield and other neuroscientist is now being applied to practical ends by a number of investigators. At least two groups, one in the United States (52, 53) and one in England (19), have now implanted arrays of electrodes in the visual centers of the brains of blind human subjects. Because the visual world is mapped systematically onto the brain, electrical stimuli delivered through different electrodes in the array can produce crude visual sensations (typically, spots of light) in different parts of the visual field. By stimulating groups of electrodes, it has been possible to elicit crude patterns of visual sensation (20, 54). A few subjects have been able to recognize Braille letters in this way and thus can read, although very slowly, "cortical Braille (53)." Very recently, Dobelle's group has linked the electrical output of a television camera to the electrode array, and one subject is able to "perceive" and identify rudimentary patterns—i.e,, a white stripe on a black background—that are actually "sensed" by the electronic circuitry of the television camera (53).

A number of problems must be overcome before cortical implants can be used to benefit blind or other neurologically disabled persons. For example, the brain may be damaged by implanted electrodes or by chronic electrical stimulation; electrodes may be degraded by the body; current methods for implanting electrodes are cumbersome; and presently used electrodes do not permit the stimulation of sufficiently small or delimited areas of the cortex. Some problems may require advances in neurophysiology for their solution; others await breakthroughs in bioengineering, electronics, or materials science. Work on new types of electrodes and on noninvasive methods of cortical stimulation, currently being sponsored by NIH, may lead investigators in entirely new directions if it is successful. Even the clinically oriented groups testing chronic implants in blind human subjects now claim to regard their research "primarily as a technique to begin investigation of dynamic pattern presentation rather than as a basis for clinically useful prostheses" (53). Nevertheless, recent promising results and current vigorous research on neural prostheses of various types, including cortical implants, make it possible to foresee development of clinically useful devices within the next few decades.

The development of cortical implant technology is being supported by several agencies. The American group doing cortical implants on human subjects has received NIH support in the past but is now supported by funds from several foundations, from industrial sources, and from their university (52–54). The British group is supported by the Medical Research Council, a Government agency (19-20). NIH, believing that a large number of technical problems must be solved before trials on human subjects will be profitable, is sponsoring work on biomaterials and electrode **design, animal** experiments on chronic electrode implantation and electrical stimulation, and basic research on the long-term effects of electrodes and brain tissue on each other. Some work is proceeding intramurally, but most is going on at universities, supported by NIH grants and contracts. NIH is also undertaking and supporting work on a variety of other neural prostheses, such as electrical control of bladder function in paraplegics. Some of these related technologies may be clinically useful well before cortical implants are fully developed and may provide useful information for developers of cortical implants.

This case raises two interesting questions. First, although clinically useful cortical implants are not yet available, ongoing research is targeted to a definite goal, and clinically useful devices may be developed within the next few decades. Is it possible to begin now to evaluate the social implications of such devices and to plan for their introduction? Second, NIH a Federal agency, is currently sponsoring research on animals, directed at solving fundamental technical problems. Meanwhile, foreign groups and privately supported researchers in the United States are already testing crude implants in human subjects. Might even rigorous efforts at technology assessment be futile if they are limited to the research programs sponsored by the Federal agency?

9. The Totally Implantable Artificial Hearts

The idea of substituting an artificial device for a damaged natural heart is an old one. The first real step in bringing this idea to fruition occurred in 1939 when John H. Gibbon, Jr., succeeded in keeping cats alive for nearly 3 hours with a

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This case is adapted from ref. 142,

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mechanical apparatus that substituted for both heart and lungs. After World War II, progress in the development of techniques for cardiovascular surgery was rapid. In 1953, Gibbon performed the first open-heart surgery on a human, using a heart-lung machine. This machine, which can temporarily bypass the heart, maintains blood circulation and also takes over the lungs' function of removing carbon dioxide from the blood and supplying it with oxygen. Gibbon's success helped to rekindle interest in a mechanical heart.

By the late 1950's progress in heart-assist devices encouraged medical investigators to consider the possibility of developing a totally implantable artificial heart with its own power supply. Proposals for further work were submitted to NIH at that time. Such proposals had to compete through the standard granting process, preventing a coordinated program effort. In the fall of 1963, the National Advisory Council of the National Heart Institute endorsed a suggestion that artificial heart research receive greater budget priority. In 1965 Congress responded by specifically designating funds for an artificial-heart program. NIH then established an Artificial Heart Program Office. The program has developed with an engineering orientation, targeted goals, and contract support, much of which went to profitmaking firms.

Several basic problems have beset the development of circulatory assist devices, including the artificial heart: materials used as pump linings have been consistently 'harmful to blood; reliable and compact pumps capable of operating for long periods have had to be developed; and efficient, unfailing energy sources are required. Strenuous attempts to cope with these problems have improved the situation, but completely satisfactory biomaterials and power sources have not yet been devised. Currently, three alternative types of power supply are being considered—biological fuel cells, conventional batteries, and a nuclear system-and developmental work on all three is being pursued.

The NIH staff was concerned that the availability of a totally implantable artificial heart might have serious implications for society. By the early 1970's, it felt that the technical feasibility of the device had been sufficiently demonstrated in animals to warrant formal consideration of social impacts. Therefore, in August 1972 the National Heart and Lung Institute (NHLI) convened an interdisciplinary panel to identify and evaluate the personal, social, and cultural implications of developing such a heart. The report (142) was published in June 1973 and constitutes the most comprehensive technology assessment done in the health field to date.

The assessment at NHLI was based on the "explicit assumption that the objectives of the NHLI artificial heart program [would] one day be realized in full" and that "certain issues connected with widespread availability" of a clinically useful device could be addressed while research program were . **still in progress (1 42). Material from that report will be used in chapter III of this report to illustrate the types of information that can be elicited when medical technologies are carefully assessed.**

AN OVERVIEW: THE COMPLEXITY OF MEDICAL TECHNOLOGY

Medical Technologies Are Diverse in Nature and Purpose

Actual medical practice often involves concurrent or sequential use of several different technologies. Nevertheless, some tentative classifications of medical tech-

nologies can be made. Such schemes might be useful in deciding whether or how to assess a particular new technology and in making prospective judgments about new technologies on the basis of previous experience or assessment.

For example, one might classify each technology in two different dimensions-according to its physical nature, and according to its purpose (122, 166):

By physical nature:

(a) A *technique* is an action of a health-care provider that does not require specialized equipment.

(b) A *drug* is a substance administered by a health-care provider to a patient. Drugs include chemicals that can be injected or ingested (such as anticoagulants, Case 5) as well as biological substances (such as vaccines, Case 3).

(c) *Equipment* includes both machines requiring large capital investments (such as the CAT scanner, Case 2; the continuous flow-blood analyzer, Case 1; or a renal dialysis unit, Case 6) and the many smaller medical devices and instruments used in medical practice.

(d) A *procedure* (such as implantation of a pacemaker, Case 7, or of a cortical prosthesis, Case 8) is a combination of technique with drugs and/or equipment.

By medical purpose:

(a) A *diagnostic* technology (such as the CAT scanner, Case 2, or the continuous flow-blood analyzer, Case 1) helps in determining what disease process is occurring in a patient.

(b) A *preventive* technology (such as a vaccine, Case 3) prevents disease.

(c) A *therapeutic, or rehabilitative,* technology is applied to an individual to give him or her relief from disease and its effects. Therapeutic technologies can be further divided into those few technologies (such as some antibiotics) that *cure* disease and those many technologies (such as renal dialysis, Case 6; cortical implants, Case 8; or the cardiac pacemaker, Case 7) that give *symptomatic* relief but do not change the underlying disease process.

(d) An *organizational* technology is used in management and administration to insure that medical practice is as effective as possible.

(e) A *supportive* technology is used to give needed services to patients, especially those ”in the hospital, such as hospital beds and food services.

Medical Technologies Are Developed in a Variety of Ways and Places

Knowledge gained from basic research may be applied to the development of clinically useful technologies quickly and directly or slowly and indirectly. In many cases, new technologies arise from the confluence of many lines of basic, applied, and clinical research, and the logic of the developmental pattern can be discerned only in retrospect (e.g., Case 7). Work leading to the development of new medical technologies may proceed in university, government, or industrial laboratories, in

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Organizational and supportive technologies are not discussed in this report.

medical centers, in clinical practice or, more often, in several of these settings, both concurrently and sequentially. The cost of technology development may be borne by philanthropic organizations (e.g., Case 3), private industry (e.g., Case 2), Government agencies (e.g., Case 9), or by combinations of funds from various sources (e.g., Cases 7 and 8). Because these developmental complexities pose special problems for the assessment of medical technologies, they will be discussed in detail in appendix A.

Medical Technologies Pose a Variety of Technical and Social Problems

Technical issues include concerns about safety and efficacy. *Social* impacts can result from special features of the technology itself or from the economic burden that its use imposes on society.

All invasive procedures, including administration of drugs as well as surgery and the use of equipment, involve some finite risk to the patient. Determination of the *safety* of new technologies is crucial because the risks that may be encountered in use must be weighed against the potential benefits in deciding how-or if-new technology is to be used. Belated discovery of toxicity, risk, or side effects can have tragic consequences for the patient. Even where the extent of risk is fairly well known, it is often difficult to weigh considerations of safety and efficacy, as illustrated in the case of radical mastectomy (Case 4).

Issues of *efficacy* are raised when proof of efficacy is lacking before introduction of a new technology, when a widely used technology is later shown to be inefficacious, or when the relative efficacy of alternative therapies is compared. The cases of oral anticoagulants (Case 5) and radical mastectomy (Case 4) illustrate some of these problems. Questions of efficacy have recently been raised about a variety of widely used medical technologies (6, 9, 37, 88, 99, 112, 130). Only 10 to 20 percent of all procedures used in present medical practice have been proven by clinical trial (213); many of these procedures may not be efficacious.

The *economic* burdens imposed by the use of medical technologies cause problems for the patient, for his family, and for society. Medical technologies contribute to rising medical care costs in various ways:

- Some new technologies require large capital investments. For example, a CAT scanner costs from $350,000 to $700,000 (Case 2) and a modern automated blood chemistry analyzer (the SMAC 60) costs $250,000 (Case 1).
- Costly supporting services are required to implement some new technologies. New personnel must be hired to operate equipment, and existing personnel must be retrained. A study of 15 Boston hospitals indicated that capital investment accounted for only about 5 percent of costs, but associated costs were much larger (47).
- Costly followup care is made possible-r even required—by some new technologies. For example, fetal monitoring during labor has led to intervention in the birth process by cesarean section (212).
- The need for continued use of technologies may lead to economic burdens. Chronic renal dialysis, for instance, requires lifetime use several times a week for most of those with end-stage kidney disease (Case 6). Each

session of dialysis is expensive, and use over a period of years results in an enormous overall cost.

- Initial proof of efficacy and reliability of new technologies may lead to overuse. Utilization rates for automated clinical laboratories (Case 1) and CAT scanners (Case 2) are rising rapidly without documented benefit to the health of either individuals or groups in society (88, 176). This problem is exacerbated by the malpractice situation, which fosters protective ordering of tests (defensive medicine).
- Technologies may be used for inappropriate purposes, thereby leading to economic as well as human costs. Variations in surgical rates between areas **(212),** systems of medical care (63), and countries (23) suggest that a certain amount of unnecessary surgery may be performed in the United States. Unnecessary surgery not only is costly in financial terms, but also causes pain, disability, and sometimes death (120, 199).

Although no definitive estimate can be made for the overall cost of medical technology, it has been estimated that 50 percent of the increase in costs of hospital care, from $13.2 billion in 1965 to $40.9 billion in 1974, was due directly or indirectly to medical technology (75, 207). The contribution of technology to costs for physician services is also substantial (217). The cost of certain technologically based activities can be estimated with more accuracy. As noted in the case of the continuous flow-blood analyzer, the costs in 1975 for clinical laboratory services were about $15 billion (21), more than 12 percent of the national health expenditure (133). X-ray services, both medical and dental, are estimated to have cost $4.7 billion in 1975 (67).

These economic burdens must be considered from the point of view of cost effectiveness. Undoubtedly, many if not most technologies in use have some effectiveness. One must then ask if society is prepared to pay for partially efficacious technologies that are very expensive. The use of Federal funds to pay for renal dialysis (Case 6) is the result of one such decision by society. New therapeutic regimens for cancer and rehabilitation devices such as voice-activated wheelchairs will pose similar problems in the future.

Medical technologies can also raise troubling *social* issues that are unrelated to economic considerations. For example, modern technology has challenged society's traditional view of death and dying. Although these issues are not new, they have been given added significance by new life-extending technologies such as artificial hearts (Case 9) and kidneys (Case 6). Modern technology can dehumanize the individual, affect the way people view themselves and others, and give awesome powers to physicians (104).

Current vigorous efforts in biomedical research seem certain to result in the development of new technologies that will pose important social problems. In the diagnostic area, use of new developments in imaging, including computed tomography (Case 2) and ultrasound, will add greatly to costs. New clinical laboratory equipment, such as centrifugal fast analyzers **(116),** may partially replace the continuous flow-blood analyzers described above (Case 1). In the therapeutic area, bone-marrow transplants are just beginning to be used for treatment of cancer patients, and their use could spread rapidly. Neural implants of electrodes to overcome neurological problems including blindness are now being developed (Case 8). Other cases, such as sex determination of unborn children,

genetic screening, and extrauterine fetal development, raise even more difficult issues concerning the future of mankind.

Although new medical technologies may cause concern, however, preoccupation with the issues that they raise must not overshadow recognition of the serious human and social problems posed by diseases for which no therapy is yet available. Modern medicine has developed a workable classification of disease and has developed sophisticated diagnostic procedures for determining what pathological condition is affecting the individual. However, basic understanding of the pathophysiology of these conditions is often inadequate, and effective medical interventions are few.

Technical and Social Issues Are Interrelated

This report will be limited to a discussion of ways to assess the social impacts of new medical technologies; methods for assessing technical concerns such as safety, reliability, and efficacy will be described in a subsequent report. Because of the separation imposed by this organization, it is necessary to state explicitly that the technical and social issues posed by new medical technologies are inextricably linked. For example, ethical considerations, seemingly remote from technical matters, can hamper the determination of medical efficacy, as noted in the case of radical mastectomy (Case 4). Unexpected toxicity or injurious side effects of new technologies can lead to social impacts that would not have arisen had the technology been safe, as shown by the well-publicized case of thalidomide. The degree of effectiveness of a new technology in combating disease determines its social impacts, and conversely, a whole variety of social and cultural factors determine the effectiveness, in practice, of a new technology. Although different methods are used to assess the technical and social impacts of new technologies, it must be recognized that problems (and their solutions) cannot, in reality, be separated.

Chapter III

WHAT ARE THE IMPACTS OF MEDICAL TECHNOLOGY?

Chapter III

WHAT ARE THE IMPACTS OF MEDICAL TECHNOLOGIES?

At present, many decisions about the development and implementation of new technologies are made on the basis of a limited number of criteria, such as:

. Technical feasibility: Can the technology be developed, and is it likely to do what it is supposed to do?

. Safety: Will the technology cause undue harm to its providers or users?

. Anticipated need or demand: Is the technology worth developing? In the private sector, economic indicators of market size or profitability may be used to estimate demand; estimates of potential need for technologies developed in the public sector may be based on both economic and non-economic factors.

The material presented in chapter II of this report has demonstrated that the impacts of many medical technologies are far broader in scope than these few criteria would imply. The development and eventual use of new medical technologies may have implications for:

. The patient;

. The patient's family;

. The society as a whole (including impacts both on tangible common goods, such as the environment, and on less-tangible factors, such as ethics, cultural values, or demographic variables);

. The medical care system;

. The legal and political systems;

. The economy (including impacts that extend far beyond the burden imposed by the direct cost of the new technology).

Each of these areas is itself complex, and the whole set encompasses a bewilderingly broad array of impacts. To clarify the nature and scope of these impacts, the remainder of this chapter presents—

. A list of questions that could be used to explore the implications of introducing a new medical technology; 1

. Some preliminary questions about the medical aims, technical characteristics, and developmental state of the new technology that must be answered before broader impacts can be considered; and

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1 The questions are drawn from issues raised by the cases in ch. 11, and on material from a variety of other sources (13, 16, 30, 43, 74, 91, 104, 123, 140, 142, 194).

- Answers to several of the questions, with reference to the totally implantable artificial heart, [2] which illustrate the types of information that one might hope to elicit.

PRELIMINARY CONSIDERATIONS: WHAT ARE THE MEDICAL AIMS, TECHNICAL CHARACTERISTICS, AND DEVELOPMENTAL STATE OF THE TECHNOLOGY IN QUESTION?

. What medical problems is the new medical technology designed to solve, and how severe are these medical problems: Does it diagnose an early form of the disease? Does it make diagnosis more reliable or valid? Does it treat a life-threatening symptom or syndrome? Does it correct an incapacitating but non-lethal condition?

The totally implantable artificial heart is designed to replace the natural heart of patients whose hearts are no longer capable of functioning adequately. The majority of these have ischemic heart disease (that is, heart disease resulting from blockages of the coronary arteries of the heart) and would soon die if untreated.

- How many people are afflicted with the medical problem?

Heart disease is the most common cause of death in the U.S. population. Many heart victims, however, could not successfully be treated by implantation of an artificial heart. From 16,750 to 50,300 people each year are estimated to be candidates for implantation.

- Is the technology a major or minor innovation? Will it radically alter medical practice or will it modify and improve established procedures?

A totally implantable artificial heart will be a major medical innovation. It would provide an entirely new way of treating patients for whom no effective therapy is presently available.

- What knowledge base underlies the proposed technology? How has the technology developed so far? What future knowledge of importance can be anticipated?

Knowledge of the anatomy and physiology of the normal heart, as well as advances in bioengineering, underlie the development. Development so far is the result of 20 years of work to adapt equipment used in open-heart surgery for long-term use. Concerted NIH support for work on the implantable heart may have speeded progress. A left ventricular assist device, or artificial left ventricle, developed largely with NIH support is a major step in the development of a totally implantable heart. Although development of the ventricular assist device is far from complete, prototype models are already being tested in pa-

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2 Material about the artificial heart, which is being developed under the aegis of the NIH, is drawn largely from the report of a panel convened by NIH to assess its social implications (142). Since that report does not contain answers to all of the questions that might be asked of a new technology, several of the questions in the present list are left unanswered. A brief description of the purpose, history, and developmental status of the artificial heart is contained in ch. 11, Case 9.

tients. Improvements in biomaterials and energy sources will be necessary before a clinically useful totally implantable artificial heart can be made. Research in these areas is underway.

. How soon can development and adoption of the new technology be expected if there are no interventions in the normal processes of research, development, testing, marketing, diffusion, and use?

Development of an artificial heart that would be suitable for clinical trials in human subjects is not anticipated in the near future. A prototype device might, however, be available within a decade.

. How effective is the procedure? Has its medical efficacy been assessed yet? How will medical efficacy be assessed? Are rigorously controlled clinical trials possible? Underway? If controlled trials are not possible for technical or ethical reasons, is there, any other way to insure that the technology is medically effective?

Because a clinically useful device has not yet been developed, no estimates of efficacy can be made. When a totally implantable artificial heart is available, controlled trials will be possible. However, it may be difficult to resist pressures from desperate patients and their families for implantation of an incompletely tested artificial heart. The artificial heart might be tested on patients facing imminent death.

. What are the potential or proven dangers of the technology to individuals using it?

For some time after its introduction, the artificial heart will be experimental, and those accepting it will face the possibility of complications and even death. If the device is nuclear powered, the individual may also face dangers from radiation exposure.

WHAT ARE THE IMPLICATIONS OF THE TECHNOLOGY FOR THE PATIENT?

. What will be the quality of life of the patient who has been treated? Normally active? Moderately restricted? Physically crippled?

A recipient of an artificial heart could reasonably expect to lead an active, productive, fairly normal life.

. What psychological effects can be anticipated? Guilt? (Because of high financial and social costs to family, etc.) Anxiety? Feelings of dehumanization? Dependency?

Anxieties and even psychoses might be precipitated in heart recipients who are preoccupied by dependence on an inorganic source of power. Such reactions have been observed in patients receiving dialysis for chronic kidney disease. Furthermore, some of the drugs that might be used as supportive therapy e.g., steroids—themselves have psychotropic effects.

. Will regimentation result from use of the technology? Loss of freedom over one's body?

If nuclear-powered artificial hearts are used, it may be necessary to identify or even monitor movement of recipients in order to protect the nuclear fuel and to recover it after death. Recipients might be required to waive some of the individual freedom most of us take for granted.

. Will use of the technology increase the probability of a lingering and painful death?

Death from heart disease is sometimes+ although not always-swift and painless. Although the benefits of prolonging life with an artificial heart are obvious, the recipient will have to be made aware of the possibility of death from failure of the implant procedure.

. Will the effects of the new technology be reversible if the patient feels that its benefits are outweighed by its drawbacks? Will the individual be able to choose to die?

Once surgery is complete, the procedure can be reversed only by removing or deactivating the artificial heart, thereby allowing the patient to die.

WHAT ARE THE IMPLICATIONS FOR THE PATIENT'S FAMILY?

. What will be the costs to the family? How will the new technology affect family structure?

Implantation of an artificial heart will permit survival of the patient, and the benefits to the rest of the family will be numerous. On the other hand, unless the cost of implantation of the heart is covered by some third-party payer, the enormous financial burdens could impoverish the patient's entire family and strain intrafamily relationships.

. Will there be any physical dangers to the immediate family?

The plutonium contained in a nuclear-powered artificial heart may, however well shielded, emit radiation that could pose some danger to family members who are frequently close to the patient.

. Will the device or procedure be psychologically acceptable to the family?

. Will active cooperation or assistance of family members be necessary on a continuing basis?

• How 'will the new technology affect individual or family budgets? What purchases will families forego if they have to pay for the new technology?

WHAT ARE THE IMPLICATIONS FOR SOCIETY?

. Will the new technology change the demographic characteristics of the society? For example, can changes in sex ratios or age distribution in the population be anticipated ?

Many candidates for heart implantation will be elderly; if the procedure is effective, the percentage of elderly in the population will increase. Also, because women are less prone to heart disease than men, effective implants may increase the ratio of men in the elderly part of the population. However, because candidates for this technology make up only a small fraction of the population, the impact will be minimal.

. Will the new technology affect reproductive capability of patients and thus change the genetic pool and the prevalence of genetic diseases?

Some cardiac disease is of genetic origin. If the artificial heart allows carriers to reproduce when they otherwise would not, then there will be an effect on the population's gene pool: the artificial heart would generate new candidates for its future use. On the other hand, if coronary disease of genetic origin does not cause symptoms until carriers are past child-bearing age, then use of the artificial heart will not affect the gene pool. In any case, the effect would be quite small.

- Will existing social value systems affect development, acceptance, and use of the technology ?

When the lives of specific, identifiable persons are in jeopardy, our society is inclined to try to preserve these lives at any cost. Society seems to emphasize development of therapeutic technology over related priorities such as disease prevention. Therefore, work on the artificial heart will probably receive continued support, and a clinically useful device will be accepted rapidly and may be paid for by Federal health care programs. In fact, a special program, such as the one for renal dialysis (see Case 5 in chapter II), may be created to provide reimbursement for heart implants.

- What kinds of people presently get help from existing alternatives to the proposed technology? Who will be eligible for help from the new technology? How will patients be selected for the procedure?

If the artificial heart works well, the demand for it maybe so great that society will find it difficult to supply the device to all who want it. Even assuming an adequate supply, society may be unwilling to supply the device at public expense to all needful patients. Convicted criminals, drug addicts, and other persons viewed as noncontributing members of society may be excluded. Any process of rationing life on the basis of social worth would have a major impact on public values.

. Will use of the new technology by an *individual* create threats to the *environment* that are properly the concern of the entire society?

If nuclear-powered artificial hearts are used, there will be a finite danger of radiation damage from the plutonium carried by mobile recipients. Particularly troublesome is the remote possibility of accidental rupture of the shielding material.

- Will introduction of the new technology challenge important beliefs and values of the society about birth, gender, bodily integrity, personal identity, marriage and procreation, respect for life, right to live, right to die, responsibility for each

other? Will introduction of the new technology result in changes in these values?

The artificial heart will raise questions about the nature of death. Thus, even if a patient showed no other signs of life, stoppage of the artificial heart seem of greater moment than turning off a respirator. For patients in whom the artificial heart merely prolongs misery, it may be necessary to develop a concept of a "right to die."

- Will knowledge be gained from implementing the new technology that will be useful for society? Will the technology be useful for nonmedical purposes?
- Will the public demand knowledge about or dissemination of the new technology? Can the public be educated to the implications of the technology? What role does the general community have in decisionmaking? Will the effects of the technology be easy to monitor?
- Will the technology alter any basic institutions of society (e.g., schools, recreational facilities, prisons)?

WHAT ARE THE IMPLICATIONS FOR THE MEDICAL-CARE SYSTEM?

- What alternative, available technologies would the proposed innovation replace? Would it be used in conjunction with or instead of available technology? Are there other proposed but still undeveloped technologies that would solve the same problem?

  There is presently no effective treatment for those with inadequately functioning hearts. The artificial heart will replace less satisfactory treatments such as heart transplantation. More effective preventive or therapeutic interventions might be developed from research, but they are unlikely to be immediately helpful to the group that would benefit from the artificial heart—the group with far-advanced disease.

- What will the impact of this technology be on the demand for and effectiveness of other procedures or services? Preparatory and followup resource needs? Other medical and psychosocial supports?

  Implantation of an artificial heart is a surgical procedure that requires sophisticated hardware. To insure the success of the procedure, however, intensive use of a variety of other technologies will be required. These include intensive-care units, pharmaceuticals, and follow-up social and psychological counseling.

- How will the proposed innovation affect future programs aimed at the development and use of other new technologies?

  Availability of an effective artificial heart will increase incentives for developing screening, diagnosis, and emergency care programs and facilities, so that potential recipients could be found and then kept alive until the time of surgery. Also, success of the program may encourage other goal-directed, technology-intensive solutions to major health problems-and their impacts will eventually have to be considered.

- Will the new technology strain existing resources? Given limited resources for the present system of medical-care delivery, which (if any) medical services would have to curtailed to provide funds and manpower for the new technology? Who will decide among competing priorities?

  The total cost of each artificial heart implantation is estimated at $15,000 to $25,000, although costs might be reduced later if large numbers of devices were used. However, risks of complications, changes in support services, and so forth, could add substantially to costs. Much of the cost would presently be covered by medical insurance, but existing patterns of coverage would make the device more available to upper than lower income groups.

- If the technology is in short supply and selection of patients is necessary, will the choice be left to the physician? Who will determine the criteria for selection?

  The device will probably be in short supply, especially in the early phases of testing and diffusion. At these early stages, eligibility for implantation will probably be determined by research clinicians. It will be up to them to develop mechanisms for patient selection and to decide whether medical status and/or "social worth" should be used as criteria.

- What will be the effects of the new technology on primary care? Will it cause a change in the ratio of family practitioners to specialists? Foster specialization? Increase professional power? Promote a technological elite? Depersonalize the relationship between doctor and patient? Enhance or challenge the trust of patients in their doctors?

  The artificial heart would be a major new development in the trend toward high-technology medicine, with all that this trend implies for specialization, depersonalization, and the delivery of care by teams located in very large medical centers. This trend conflicts with current efforts to utilize family practitioners to provide better ambulatory care with emphasis on prevention.

- Will the new technology affect the values of health professionals?

  Physician behavior is now largely guided by the precept that one must do whatever is possible for the individual patient. As physicians see enormous sums spent on heart implants at the expense of preventive or therapeutic programs that would benefit many, they may begin to question this dogma.

- If the new technology proves effective, will there be pressure for widespread use? Who will apply pressure: patients, physicians, manufacturers? Would excessive use result in adverse effects? Will designation of the technology as "experimental" curtail use (or overuse) ?

  There will undoubtedly be pressure to implant the artificial heart in patients facing imminent death. Judgments will have to be made about how quickly successive human trials should follow successful or unsuccessful experiments, and which, and how many, medical institutions should participate in the experiments.

- Are present standards for the protection of human subjects and informed consent adequate for the case at hand?

The artificial heart raises difficulties because of the likelihood of death without it. The process of obtaining informed consent should include full and candid disclosure of the risks and benefits of implanting the artificial heart. The patient will have to understand that many problems remain the subject of further scientific study.

- Will geographic variations in availability of the new technology be important?

  Initially, only a few medical centers may have the personnel and facilities to implant an artificial heart, This may be a good thing, since expensive and wasteful duplication of facilities would be avoided, and since the more frequently a surgical team does a procedure, the better its results are likely to be. However, procedures would have to be developed to insure access of patients to appropriate facilities even if the physical distance between home and the hospital is great.

- Does the technology address a serious deficiency in medical care?

- Will use of the new technology cause changes in manpower needs? Will more or fewer physicians, paraprofessionals, technicians, etc., be required? New administrative personnel or structures? Changes in the institutional or geographical distribution of personnel?

- Will the new technology affect the status of medical personnel? Will it require changes in current practices of licensing or training of practitioners? How will the technology affect the income of health-care providers?

- Will changes in nonmedical systems (e.g., schools) be necessary to insure effective medical use of the new technology?

- Will malpractice insurance rates or regulations be affected?

WHAT ARE THE IMPLICATIONS FOR THE LEGAL AND POLITICAL SYSTEMS?

- Will problems of justice, access, or fairness arise? Will they lead to litigation?

  If artificial hearts are initially limited in quantity, life-and-death decisions will have to be made about their allocation. Particularly if the costs of the implant are publicly supported, allocation decisions may be contested in the court system. On the other hand, use of artificial hearts rather than human heart transplants would eliminate the risk of legal proceedings arising out of questions concerning the death of organ donors.

- Will the manufacturer be liable for damages resulting from failure of the technology? Will liability extend only to damage to the individual or will it cover environmental effects as well?

  Liability for failure of the device as opposed to surgical failure might fall on the manufacturer, since physicians and hospitals, as well as patients' families, could bring litigation.

- Will the quality (efficacy, safety, etc.) or use of the new technology require legal regulation? Who will formulate the regulations, and how will they be enforced?

In the case of a nuclear-powered artificial heart, new legislation might be needed to insure prompt identification of bearers and postmortem removal of the fuel source. A large staff might be necessary to enforce such regulations.

. Will use of the new technology require changes of the definitions of death or suicide?

By maintaining circulation and heartbeat independent of other vital functions, the artificial heart would render some ideas about death moot; more reliance would have to be placed on alternate definitions such as "brain death. "

. Can political pressures for increasing availability be anticipated? What individuals or groups will be likely to be politically active in urging acceleration or deceleration of Government support for the new technology?

As in the case of kidney dialysis (see ch. II), availability of a lifesaving but exceedingly expensive treatment such as heart implantation might trigger pressure for its public funding. The ability and desire of the Government to finance implants would have to be considered. Additionally, such pressure-r enactment of a support program—might lead to broader consideration of the financial mechanisms for delivery of health services generally.

. Will patients have the legal right to accept or refuse treatment? Will new regulations be required to insure voluntary, informed consent?

WHAT ARE THE IMPLICATIONS FOR THE ECONOMIC SYSTEM?

. What is the projected or present overall monetary cost of adopting the new technology? Can cost reductions or increases be anticipated in the future?

If the totally implantable artificial heart were available today, the direct costs of its use would be at least $500 million per year (based on an estimate of 20,000 eligible patients per year). This figure does not include a number of indirect costs that have yet to be properly calculated.

. What are the economic implications for the medical-care system? Will overall costs be increased or decreased? Will additional personnel or large capital expenditures be required to support the technology?

Overall medical costs will be increased; large capital expenditures and additional personnel will be required to support medical facilities capable of carrying out heart implants.

. How do costs of the new technology compare with costs of potential substitutes?

Alternative treatments are unsatisfactory for the group in question.

. Will income maintenance be required for those using the technology? What are the implications for programs of disability or life insurance? Pension funds? The Social Security System ?

Artificial heart recipients of young or middle age will be able to return to work and support themselves. However, an expanded population of the

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elderly, kept alive by implanted hearts, might strain the resources of pension funds or the Social Security System.

- Who will pay? Who can be expected to pay? Will Government support be required for development and/or use of the new technology?

  Without Government support, development will be slowed and clinical use will probably be limited.

- What market forces will promote or retard development and use of the new technology?
- Will nonmedical sectors of the economy be affected? (E.g., will changes in diet affect food consumption?)
- How will the technology affect the national economy? Will development and use produce jobs? Who will pay for development? How will this affect overall productivity? Will the tax structure and rates be affected?
- If large-scale Government support is requested, with what national priorities will the new technology compete? What 'Government programs might suffer if funds are diverted to the new technology?

Although many of the questions in this list are relevant to the case of the artificial heart, no single medical technology can be expected to exemplify all impact areas. The importance of some of the questions that are not applicable to the artificial heart can be dramatically illustrated by material drawn from other cases.

For example:

CHOOSING THE SEX OF CHILDREN

- Would the technology have any effects on the demographic structure of the population?

  It is already possible to determine the sex of a child in the uterus, and to carry out an abortion if it is not of the sex desired. Within the next few years, methods for predetermining the sex of children may become available. Use of these new techniques could have important impacts on such demographic characteristics as the ratio of male to female births, average family size, overall birth rate, and the sex composition of families.

PSYCHOSURGERY

. Does the technology affect the patient's right to give informed consent?

Psychosurgery raises important ethical questions about informed consent. Some investigators believe that violent behavior is related to physical brain dysfunction, which can be controlled by destruction of parts of the brain. The effects of this procedure are open to serious question, and the long-term implications of psychosurgery are not understood. However, the incidence of

psychosurgery may increase in the years ahead because of increasing public concern about violence and disillusionment with other forms of therapy. Two questions about informed consent arise. First, if candidates for psychosurgery are chosen because they are judged to be irrational, might "informed consent" be given little weight? Second, a prison system might offer reduced sentences or outright freedom to those willing to submit to psychosurgery. Would these circumstances constitute inherent coercion?

- Is the procedure reversible?

  A procedure making destructive lesions in the brain is not reversible-a piece of the brain cannot be replaced, and no form of prosthetic device is available. If undesired effects result from the surgery, there would be no way to reverse them. Possible ill effects would include mental dullness, epilepsy, and personality changes.

Thus, specific questions will be more or less important, depending on the technology that is being considered. Furthermore, it may be necessary to pose the questions in different ways in order to elicit important information about different types of medical technology. As discussed in chapter II, technologies are used for different purposes such as the prevention, diagnosis, and treatment of disease. The implantable artificial heart, used above to illustrate a variety of social impacts, is aimed at treating disease. In examining a diagnostic technology, one would have to consider the therapeutic measures that would be available once disease was diagnosed, and the impacts of using those treatments.

The questions presented above illustrate the broad range of social impacts that might accompany introduction of a new medical technology. The next chapter describes how the methods of technology assessment can be used to ask these questions, in a formal and systematic way, of developing medical technologies.

Chapter Iv

THE IMPACTS OF MEDICAL BE ASSESSED?

Chapter IV

HOW CAN THE IMPACTS OF NEW MEDICAL TECHNOLOGIES BE ASSESSED?

The preceding chapters of this report have demonstrated the variety and nature of impacts that may accompany or follow the introduction of new medical technologies. It might be valuable to introduce some consideration of these impacts into the decisionmaking processes that govern the development and early use of such technologies. If these impacts are to be systematically considered, one will require methods of prospective analysis—that is, methods that can be applied while the technology is still being developed, to define and evaluate the potential impacts of its eventual introduction into use. The first three parts of this chapter describe one such method, technology assessment, discuss some limitations of this method, , and outline several alternate modes of assessment. The final section describes how the general methodology of technology assessment could be applied to developing medical technologies.

TECHNOLOGY Assessment

Technology assessment is a comprehensive form of policy research that examines the short- and long-term social consequences (e.g. societal, economic, ethical, legal) of the application or use of technology. It is an analysis of *social* rather than technical issues, and it is especially concerned with unintended, indirect, or delayed social impacts (203, p. 28). Technology assessment is neither a panacea nor a new discipline. In essence, it is simply a broader form of policy research than is commonly conducted. The goal of technology assessment, as of all policy research, is to provide decisionmakers with information on policy alternatives, such as allocation of research and development funds, formulation of regulations, or development of new legislation,

There is considerable confusion about the term "technology assessment," and it is often used to mean different things. For example, some use it as if it were synonymous with technology-related research such as forecasting, market research, or technology transfer. Others use it to mean a political strategy to restrain or plan technological innovation. Still others use it as a general figure of speech synonymous with casual judgment about technology, such as a consumer's decision to buy or not to buy a device. While such activities maybe vital, they do not constitute technology assessment by this definition.

The term "technology assessment" was first used by the Subcommittee on Science, Research, and Development of the House Science and Astronautics Committee of the U.S. Congress in 1965. Hearings were held at a time of rising public alarm over alleged hazards to life and health resulting from contamination of the

[1] A draft concept paper by Sherry R. Arnstein, delivered at a staff seminar of the National Center for Health Services Research on May 12, 1976, was helpful in preparation of this section.

environment by byproducts of chemical and industrial processes. Since that time many academic and professional seminars have explored the concept, numerous publications have described elements of a technology assessment, technology assessments have been carried out (42, 51, 133, 189), and congressional hearings and reports have further explored the developing field (159, 200). By 1972, V. Coates was able to document that of 86 offices in Federal executive agencies identified as chiefly responsible for projects and programs of technological nature, 13 percent consistently performed or sponsored technology assessments and regarded technology assessment as their major responsibility; an additional 63 percent occasionally performed or sponsored technology assessments of some type. Approximately 100 such studies had been done by 1972 (36).

Technology assessment has several features that distinguish it from other ways of examining the societal impacts of a proposed new technology. These features are important both in the process of doing a technology assessment and in the product that emerges. Some of the most important features of technology assessment are:

- Technology assessment is based on an explicit analytic framework, which is specified before the study begins. Although this framework may be modified as the study proceeds, its existence helps to insure that the implications of introducing a new technology will be systematically identified and examined.
- Technology assessment is comprehensive in its scope, examining impacts on social, ethical, legal, and other systems that may not be immediately obvious. Furthermore, a technology assessment considers "higher order impacts" (that is, impacts of the impacts). Some impacts are presently examined in the planning stage (e.g., through economic evaluations), but technology assessment considers a wider range of factors.
- Technology assessment is carried out by a multidisciplinary group, because it requires wider expertise than any individual or single disciplinary group could be expected to possess.
- Technology assessment explicitly identifies the groups that will be affected by the proposed technology (the "parties at interest") and evaluates the impacts of the technology on each party.

Technology assessment can be "problem-driven" or "technology -driven." In other words, a technology assessment could start from a problem—in medical care, a disease, such as lung cancer-and attempt to assess alternative solutions to that problem. These might include policy actions going far beyond the medical-care system, such as abating air pollution or banning cigarettes. A problem-driven assessment might, however, be confined to the medical-care system, and attempt to compare only traditional and proposed medical therapies. A technology-driven assessment would start from the technology itself and attempt to measure its impacts.

One important question in technology assessment is how to handle the societal values on which the analysis is based. Some argue for value-free assessments, in which facts and analysis are presented in as objective a way as possible. Others argue that values will necessarily be implicit in any analysis and should be made explicit from the beginning (4, pp. 171–172). One method for dealing with

value differences is to involve as broad a group as possible in preparing the assessment, including adversaries on certain issues. In many cases, it may be desirable to represent the interests of each party, including (or especially) the general public, in some way as the assessment is prepared. For example, an advisory board might include representatives of different affected groups (14).

Whatever the approach taken or the technology to be examined, a comprehensive assessment would include the following elements (4, pp. 13–14):

1. A statement of the problem to be considered—usually restated or recast after analysis is underway.
2. A definition of the system (technology) and specific alternatives that could accomplish the same objectives.
3. Identification of potential impacts.
4. Evaluation of potential impacts.
5. Definition of the relevant decisionmaking apparatus.
6. Presentation of options for decisionmakers.
7. Identification of parties of interest, potential "winners" and "losers," ineluding both overt and latent interests.
8. Definition of "macroalternatives", not alternative technologies as considered in 2, but broader alternative solutions to the medical problem that the new technology is designed to solve.
9. Identification of exogenous variables, systems, or events that may affect the system.
10. Conclusions-and possibly recommendations.

THE LIMITATIONS OF TECHNOLOGY ASSESSMENT

Although technology assessment is important and promising as a method of predicting and dealing with societal impacts of technology, there are problems in applying technology assessment in practice:

1. The field is still a new one. There is no standard, usable method for performing a technology assessment.
2. Medical technologies are diverse and have complicated patterns of development. Therefore, it is uncertain that there will ever be a standard format for assessing medical technologies.
3. Technology assessments are hampered by weaknesses in the tools and techniques of social science (4) that must be used to calculate social impacts.
4. Groups carrying out technology assessments have had great difficulty establishing boundaries for their studies.
5. Study groups have had difficulty achieving profitable cooperation and communication among experts from different disciplines working on research teams.
6. Coates found that the average cost of comprehensive technology assessments was $381,000, with an average elapsed time of 16 months (36). This investment automatically limits the use of technology assessment to particularly troubling problems or technologies.

It must be emphasized that technology assessment is a new field, and many of its problems relate to this fact. It would be unrealistic to expect consistently ex-

cellent results from a field that is less than 10 years old. Few assessments have been done so far and little time has elapsed since their completion. It is too early to know how useful technology assessment has been and what purposes it can serve. The process of actually performing assessments will surely contribute to the solution of troubling methodological problems.

ALTERNATIVES TO COMPREHENSIVE TECHNOLOGY ASSESSMENT

A comprehensive technology assessment, costing hundreds of thousands of dollars and lasting for more than a year, cannot be performed for each developing technology. It is possible, however, to perform limited assessments (sometimes called "mini" or "micro-assessments"), either in preparation for or in lieu of efforts on a larger scale. There are also a number of less comprehensive methods for assessing impacts that might precede, be included in, or take the place of a complete technology assessment; such analyses are sometimes called "Partial" technology assessments.

In the economic sphere, cost-benefit, cost-effectiveness, or other analyses introduce considerations that mere cost comparisons neglect (110-111). Cost-benefit studies are exceedingly difficult to do in the medical-care area because of the difficulty in quantifying benefits in monetary terms. Cost-effectiveness studies, however, requiring nonmonetary quantification of relative benefit, are more frequently feasible (126, 127, 162, 179).

Other academic or disciplinary assessments are also done, often on Government grant or contract. Sociological, ethical, public health, economic, and other discipline-oriented studies have provided insights into the process of introduction of new technologies, as well as their benefits and negative impacts. Such studies, coming from outside of the medical establishment, have provided some critical and objective evaluations of new medical technologies (69, 71, 187, 192).

Even within the boundaries of the scientific-medical establishment, there are ways to introduce broad considerations into the assessment protocol, albeit in an unstructured way. For example, the national advisory councils of the NIH categorical institutes include nonscientists who consider nontechnical issues as part of their charge. The Director's Advisory Committee at NIH has broad functions relating to NIH as an institution and has considerable potential for assessment of new research findings, a potential realized, for example, when the Advisory Committee recently made recommendations to the Director of NIH on guidelines for recombinant DNA research (150). Similarly, human experimentation committees that oversee and regulate clinical investigations on human subjects in medical schools, hospitals, and research establishments are intended to consider ethical as well as medical implications of the proposed research procedures (8). Finally, proposals to include impact statements in NIH grant or contract proposals would fall into this class of assessment.

Broader assessments are possible when input is obtained from interested, concerned, or knowledgeable parties outside of the medical establishment. Some familiar forms are (28, 108):

Public hearings: Public testimony was solicited and presented during the Director's Advisory Committee meeting at NIH on recombinant DNA research mentioned above.

- Publicly funded workshops for interested citizens: The National Academy of Sciences is sponsoring a series of forums for citizens on science.
- Public ombudsmen: This mechanism seems to have been little used in the area of the public role in science.
- Congressional hearings: With the growing role of Congress in the health-care system, the importance of such public hearings has already increased (106, p. 129).

ASSESSING MEDICAL TECHNOLOGIES

Perhaps the best way to define methods for technology assessment is to use the experience gained from assessments that have already been completed. Despite the steadily increasing number of available assessments, however, only a few medical technologies have so far been formally assessed:

. Preliminary and incomplete assessments of four medical technologies (in vitro fertilization, methods for choosing the sex of children, ways to retard aging, and technological ways to modify behavior) were sponsored by the National Academy of Sciences (134).

. An assessment of the totally implantable artificial heart (discussed in detail in chs. II and III of this report) was supported by the National Institutes of Health (142).

. Two assessments of medical technological areas (rehabilitation technologies and life-extending technologies), funded by the National Science Foundation, are currently underway.

These efforts, although valuable, provide a sparse background for further work. If medical technologies are to be more frequently, completely, or systematically assessed, three questions must be answered:

. How will medical technologies be selected for assessment?

. How will assessments be conducted?

ž How will the results of assessments be used?

Selecting Technologies for Assessment

In planning to implement programs of technology assessment, one must first complete a list of candidate technologies and then adopt some criteria to select among them. Certainly a large number of minor innovations or modifications of medical practice would not merit assessment, and one does not know whether the list of candidates would be long or short. For example, a preliminary list of candidates might include:

. Immunotherapeutic and immunosuppressive drugs.

. Remote medical monitoring equipment.

. Techniques for electrical stimulation of the central nervous system to modify behavior.

- Artificial organs, such as implantable hearts, kidneys, livers.
- Neural prostheses (see case 8 in ch. II for a specific example).
- Male contraceptives.
- Automated physical examinations.
- Gene modification therapy for inherited diseases.
- Techniques for fetal monitoring and amniocentesis.
- Reversible surgical contraception,
- Self-administered chemical abortifacients.
- Bone-marrow transplants for cancer or immune-deficiency diseases.
- Vaccines for new strains of flu and other viral diseases.
- Limb prostheses.
- Methods to determine or choose the sex of children.
- Fertilization and/or embryonic development outside of the body.
- New imaging devices for diagnostic use (e.g., emission tomography, and new developments in ultrasonography and transmission tomography).
- Rational development of psychotropic drugs for mental illness or other behavioral or affective anomalies.
- "Intelligence testing" by electrophysiological means.
- Organ and organ system banks.

On the assumption that initial lists of candidate technologies for assessment are often unworkably long, Coates (35) and others have proposed criteria for setting priorities and making selections among the candidates. Nearly all of the criteria, however, are subsumed by two simple questions: *Can the technology be assessed, and is it worth assessing?*

Can the technology be assessed?

In some cases, the data that would be required for analysis and assessment might be unavailable completely, or available in only an unusable form. The generation of new data or reorganization of old data might, according to Coates, sometimes be so difficult that it would obviate the possibility of effective assessment. Even if data are available, one must ask whether their analysis is within the competence of the agency or institution being asked to perform the assessment. Finally, some preliminary consideration must be given to the question of whether assessment of a particular technology holds the possibility of reducing uncertainty, defining issues, or structuring arguments; in some cases, it may not.

Is the technology worth assessing?

Although the scale of a proposed technology and the scope of its impacts will be largely unknown before assessment is attempted, it may be possible to make some preliminary estimates. In general, the greater the scale of an enterprise, the wider the scope of its impacts, and the higher its projected cost, the more suitable a candidate for assessment it is. Other factors may also play

a role in deciding whether a technology is worth assessing. In some cases, similar technologies already will have been assessed, obviating the need for completely new effort. Conversely, some technologies may epitomize problems ‘or impacts common to many technologies, and the potential for generating transferable information may make them especially suitable for assessment. Whether anyone will listen to or be affected by the results of an assessment should also be considered.

If the formulation of policy related to a technology is politically sensitive, inappropriate to Government agencies, or clearly beyond the responsibility of any identifiable institution, then there may be little value in assessing that technology. Finally, the stage of development of each technology must be considered. Some technologies may be so poorly developed or speculative that it would be difficult to intelligently define their characteristics, forecast their impacts, or formulate rational policy. In other cases, technologies may be so completely developed or even implemented that assessment would come too late to have significant utility.

Conducting a Technology Assessment

The tools and techniques that have been used in the assessment of nonmedical technologies have been described extensively **(4, 34, 91).** Possible institutional formats for assessing medical technologies will be discussed in chapter V. It will be the first duty of whatever institutions may be chosen to consider the range of techniques available, and to adapt them for the purposes of assessing medical technologies. Whatever the methodology and the institution, however, comprehensive technology assessment will undoubtedly entail applying the 10 elements described above (p. 47) to the medical technology in question:

. Define” the medical problem addressed, and the medical technologies proposed (elements 1 and 2). Ask questions about the aims, technical characteristics, and developmental stage of the technology, such as those enumerated on pages 32-33 (“Preliminary considerations, ” ch. III). Consider alternative forms of the technology available, proposed, or being developed so that different but related technological solutions to a common problem can be compared.

. Identify and evaluate impacts (elements 3 and 4). Chapter III includes a list of questions designed to elicit information about the implications of a new medical technology for the individual and for family, social, medical, legal, economic, and political systems. These questions may provide a way to begin searching for impacts of a medical technology and may suggest other impacts that would not otherwise have been apparent. Evaluation of the possible impacts may require calling on the expertise of lawyers, sociologists, psychologists, economists, and other professionals, as well as on medical personnel and representatives of the public.

. Identify the decisionmakers and consider the decisions that they might make (elements 5 and 6). Find the people or institutions, either in the Government or in the private sector, that are responsible for formulating policies that relate to the technology being assessed. Determine what scope of responsibility and authority each one has, and what types of decisions each could make to affect the development and use of the technology being assessed. In some cases, the available policy options might be presented explicitly and in some detail.

. Identify the "parties at interest" (element 7). Identify all of the people, groups, and institutions that will be affected by the new technology or by decisions relating to it. For medical technologies, obvious candidates include patients, physicians and other health personnel, hospitals and medical centers, third-party payers, and public and private developers of technology. Identification of the impacts of the new technology (element 3) and of the decisionmaking apparatus (element 5) will reveal other, possibly less obvious parties at interest. The explicit identification of parties at interest is important, not only because it focuses attention on the potential "winners" and "losers" resulting from technological innovation, but also because it specifies the range of interests and viewpoints that will have to be considered as policy is eventually formulated.

. Define "macroalternatives" to the technology being assessed (element 8). In element 2, alternative technological tactics to solution of a medicaI problem will have been identified and compared. It is important to consider alternative strategies that purport to solve the same medical problem in very different ways, and to consider the effect that the technology in question will have on the development and implementation of these alternatives. For example, in assessing a therapeutic technology, one might consider proposals for prevention of the disease in question. It would be legitimate, in this context, to ask how reasonable, feasible, or desirable these alternatives are and whether heavy investment in or implementation of the therapeutic technology would encourage, discourage, or complement their development and implementation. Excessively detailed assessment of "macroalternatives" could lead to undesirable expansion of the scope of the technology assessment being performed. However, ignoring such macroalternatives entirely might result in subordinating the problem at hand to the particular technology, and in ignoring an important class of policy alternatives. .

. Identify variables, systems, or events that may affect the development or use of the technology being assessed (element 9). This step has two important purposes. First, it requires that assumptions underlying the evaluation of impacts be made explicit. Assumptions about institutional structure and stability, about economic and manpower trends, or about population, lifestyle, and social values almost inevitably underlie each assessment, and it is worthwhile to examine these assumptions, both to question their validity and to see how supposedly objective analysis depends on them. Second, this exercise may help to identify previously unanticipated changes (for example, in social systems) or events (for example, economic depressions) that may materially affect the way in which the new technology will be developed or used.

. Conclusions and recommendations (element 10) are demanded in some assessments, while in other cases political considerations dictate that these elements be omitted. Their inclusion and form will, in any program of technology assessment, be dictated by the institutional position and responsibility of the team doing the assessments.

Even among technologies selected for assessment, many will not merit *comrehensive* technology assessment. One might begin to identify and evaluate the impacts of each new technology (elements 3 and 4) in an informal way by asking questions such as those listed in chapter III of this report. Appropriate further steps could then be planned, whether they be specialized economic analyses, attempts to

gather public opinion, or perhaps even comprehensive technology assessment. For example, OTA's Health Assessment Program recently initiated a study of the CAT scanner, a new diagnostic technology (Case 2 in ch. II). The staff began by conducting a "micro-assessment" which consisted of studying the technical and medical aspects of CAT scanning and asking the impact questions in chapter III. Although there are ethical, legal, and societal implications, most of the important impacts that could be identified related to medical and economic issues. Further OTA efforts will therefore be concentrated in these two areas; comprehensive assessment will not be attempted at this time.

Using the Results of a Technology Assessment

As noted above, too few technology assessments have been completed to know how the information they elicit and the recommendations they propose will be used. Furthermore, even when more assessments are available, their uses will vary with their scope and quality as well as with a variety of other endogenous factors including political considerations and the institutional setting of the group performing the assessment. However, it is already possible to imagine a number of possible outcomes of technology assessment.

Two outcomes that are frequently predicted and sometimes feared are:

- Nothing will happen. The assessment may fail to identify workable and beneficial policy changes or may conclude that the present policy is, in fact, the most desirable. Alternatively, the results of the assessment, however solid and well documented, may be overshadowed by political, economic, or other considerations.
- Development of the technology will be blocked. The assessment may find sufficient unintended or unanticipated consequences of the new technology to justify termination of all programs for its development. In some cases the drawbacks, however limited or qualified, maybe sufficient to arouse public opinion and force termination of the project.

Between these two extremes are a large number of possible outcomes of technology assessment that might modify relevant policy in other ways:

- Development or use of the technology might be expedited if new, unanticipated benefits are revealed by the assessment.
- The technology might be applied to new or expanded ends, if assessment reveals aspects or uses that had not been envisioned by the original developers.
- The assessment might provide useful information to parties at interest, including developers, that could be used as development and implementation proceed.
- Potential providers of the new technology and other parties in the marketplace may be able to plan ahead for the implementation of the new technology. If changes in systems (including reimbursement schemes, other technologies, or institutions) will be required, the groups responsible for making these changes will have a headstart in formulating policy.

. The assessment may reveal ways to implement (or develop) the new technology in an incremental fashion. For example, limited experimental programs of use might profitably precede large-scale implementation in some cases. In other cases, there might be ways to develop and test portions of the new technology (e.g., a left ventricular assist device instead of a totally implantable artificial heart) instead of adopting an all-or-nothing approach.

. If potential drawbacks to the new technology are identified but cannot be adequately evaluated, the assessment might stimulate research aimed at better understanding of such risks.

. If drawbacks to the new technology can be predicted with some confidence, the assessment might stimulate new programs of R&D aimed at developing alternative forms of the technology that minimize its drawbacks and maximize its benefits.

. If the risks or drawbacks are intrinsic to the technology, but the benefits are large, assessment might stimulate development of programs of technologies to counteract or correct the drawbacks.

• Assessment may reveal the need for new controls related to the development or use of the new technology. Agencies or legislative bodies might profitably use the results of assessment in considering if and what new regulations, taxes, prohibitions, or laws would be socially desirable.

. In many cases, assessment may reveal impacts of the new technology but may not be able to evaluate their importance. Programs of continued surveillance might then be instituted to monitor the continued development and implementation of the technology to insure that appropriate information will be made available to responsible parties in a timely fashion.

. If uncertainty about the drawbacks of the new technology is sufficiently great, or if it is difficult to balance large benefits and drawbacks, assessment may cause delays in development or use of the technology, while more information is gathered or while public response and opinion is measured. These "moratoria," whether short or long, formal or informal, could provide a desirable alternative to a policy of proceeding with expensive programs that would be wasteful, costly, difficult, or politically impossible to "turn off" at a later stage.

Whether technology assessment would have any or all of these outcomes is, at present, a matter of speculation. Any decision to implement programs of assessment must rest on the belief that more and better information is needed in making decisions about medical technology and the hope that the results of assessment can be profitably intercalated into what is already a complex decisionmaking process.

Chapter V

WHAT ARE SOME OPPORTUNITIES FOR ASSESSING THE IMPACTS OF NEW MEDICAL TECHNOLOGIES?

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Chapter V

WHAT ARE SOME OPPORTUNITIES FOR ASSESSING THE IMPACTS OF NEW MEDICAL TECHNOLOGIES?

This report has described a broad range of impacts that might accompany or follow the introduction of new medical technologies into the medical-care system and has discussed some methods for identifying and evaluating these impacts. The impacts range from psychological effects on the patient or his or her family to threats to the environment, from requirements for new types of medical manpower to changes in society's concept of death and dying. Methods for evaluating these impacts include the new field of technology assessment, as well as a variety of less comprehensive methods.

If technology assessment is applied more often and more effectively to medical technologies during their development, information could be gathered that would be useful in—

- Making decisions about priorities for research and development, and
- . Planning for the eventual introduction of new medical technologies.

In addition, technology assessment might provide a new forum for communication of biomedical scientists and policy makers with each other and with the public. Effective programs of assessment could—

- Encourage more effective education of and communication with the public on issues concerning medical technology;
- Allow opportunities for more effective public input to decisions dealing with the development and use of new medical technology;
- Improve technical input to political decisions about research policy; and
- Tap the resources of social responsibility already present in the scientific community.

Technology assessments could be conducted in a variety of ways and in any of a variety of places, either within or outside of the Government. The initial policy decision that must be made is whether or not the Federal Government should conduct, administer, or support programs of medical technology assessment. If these activities are considered desirable, then one must decide which organizations or agencies should be responsible for such programs. The following options identify several organizations within the Federal Government that might be considered. The options are not mutually exclusive-one could select none, any, or *several* of them. Furthermore, within each organization, assessments could be conducted in any of a variety of ways. For example, Government employees could conduct the assessments, or the organizations could award grants or contracts to groups in universities or consulting firms. The options that follow do not discuss or compare these approaches.

TECHNOLOGY ASSESSMENT AT THE NATIONAL INSTITUTES OF HEALTH

Funding of biomedical research is largely Federal, and 63 percent of Federal support is administered by the National Institutes of Health (NIH). NIH carries out its responsibilities through 11 categorical institutes, each of which awards grants and contracts for "extramural" research (at universities or other institutions) as well as carrying out "intramural" research (in NIH-operated laboratories and clinics).[1] Each categorical institute is charged with supporting or conducting research aimed at understanding and amelioration of a particular class of diseases. Determination of priorities, embodied in allocation of funds, occurs at three levels: among institutes (by congressional appropriations), within each institute (by line items in appropriation bills, at various levels of the executive branch, and by administrators and advisory councils within each institute), and among competitors for research funds (by peer review groups for grants and by NIH staff for contracts).[2]

As the leading Federal agency involved in biomedical research and medical technology development, NIH might be considered as a site for programs of medical technology assessment. The administrative and intramural staffs have, collectively, a wide range of expertise in matters pertaining to medical technologies. This expertise often extends to areas in which NIH is not directly conducting or supporting programs of technology development. In many cases, NIH supports research on, and thus has knowledge of, new medical technologies that are being developed in clinically useful form elsewhere (for example, see Case 8 in ch. II). Even if development is occurring exclusively in other agencies or in the private sector, NIH staff might provide a central repository of knowledge and informed judgment. Thus, groups at or supported by NIH could assess technologies being developed at NIH, technologies being developed elsewhere with NIH support through the extramural grants and contracts programs, and some technologies whose development is supported by other sources of funds,

Programs of technology assessment at NIH could be implemented at several levels:

Option 1: Programs of medical technology assessment could be conducted or administered by staff in the Office of the Director of NIH. This staff could be expanded as necessary to carry out such a program. The Director has an Advisory Committee, with members from within and outside of the scientific community; this Committee could play a role in oversight and review of assessments performed through the Director's Office.

Option 2: A new unit could be formed at NIH. NIH already has administrative entities such as the Division of Research Grants (DRG) and the Division of Research Services (DRS). These units are separate from the 11 categorical

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[1] One institute, the National Institute of General Medical Sciences, has no intramural program.

[2] The organization of NIH is discussed in more detail in sec. D of app. A.

institutes, but work with them to carry out specialized functions. Such a unit could be formed to conduct or administer programs of medical technology assessments.

Option 3: Technology assessments could be conducted in or administered through the offices of the directors of the categorical institutes. Like the Director of NIH, each institute director has a staff and an advisory council which could be involved in assessments. If this option were adopted, each institute would have the responsibility of assessing technologies whose development it supports or about which it has special expertise. The National Heart, Lung, and Blood Institute, for example, might assess not only innovations in cardiovascular medicine that it is developing (see Case 9 in ch. II), but also other technologies addressed to medical problems that fall within its categorical mandate (see Case 7 in ch. II).

Option 4:. Many of the activities conducted or supported by each categorical institute are organized as programs, divisions, or task forces. Research on the artificial heart, for example, is supported by the Artificial Heart Program in the National Heart, Lung, and Blood Institute (see Case 9 in ch. II), research on breast cancer is overseen by the Breast Cancer Task Force in the National Cancer Institute (see Case 4 in ch. II), and research on cortical prostheses is administered by a Neural Prostheses Program in the National Institute of Neurological and Communicative Disorders and Stroke (see Case 8 in ch. II). Assessments of many developing medical technologies could be conducted or administered by the staffs of the appropriate administrative units within each institute.

Option 5: Technology assessments could be conducted or administered by groups composed of members drawn from the staffs of several categorical institutes or of several programs or divisions. Often several institutes have interests in a particular medical technology; for example, the National Cancer Institute and the National Institute of Neurological and Communicative Disorders and Stroke are both involved in work on the CAT scanner (see Case 2 in ch. II). Groups with representatives of involved programs or divisions could be permanently constituted, or ad hoc groups could be created for specific assessments. In either case, a small permanent administrative staff might be required to set up, maintain, and support such groups.

Choosing among these five options involves two converse considerations. On the one hand, assessments conducted close to the research programs could be expected to ask more precise and meaningful questions and to obtain more reliable and useful information. On the other hand, assessments conducted at some distance from the programs might be somewhat more objective, less preoccupied with parochial concerns, and more able to include a wide variety of disinterested parties and viewpoints.

Another mechanism could be used, either in addition to or instead of the options listed above, to identify new medical technologies at the earliest possible stage of their development, and to identify some of their potential social impacts. The investigators performing grant-supported basic research are perhaps in a good position to identify potential applications or social implications of their work. It might be desirable to tap this rich source of information. Presently, NIH grant applications request some statement about the significance and relevance of the proposed

research; however, the information elicited is often vague, there is a powerful incentive for applicants to make self-serving statements, and the relevance must be assessed before the research is done. Alternatively, NIH or other agencies that award grants might request a forecast or "impact statement" from investigators as part of the grant completion reports, which are already routinely required. By divorcing such speculation from the grant application process, one would encourage researchers to be more realistic. By requesting the information *after* the research project is complete, one would allow investigators to reflect on initially unforeseen outcomes, applications, or implications of their work.

Such reports might provide a sound basis for assessing the implications of potential technological advance after new knowledge is acquired through basic research but before it is applied. Serving as an "early warning system" for technological innovation, these statements could be used to help NIH in setting priorities, to encourage researchers to be aware of the societal implications of their work, and to give policy makers time to prepare for unanticipated technological advances in medical care.

Option 6: NIH grant and contract recipients could be required to submit a forecast or "impact statement" concerning their research as part of their completion reports.

It must be recognized, however, that one can seldom predict either which line of research (if any) will lead to a particular medical advance, or which medical area (if any) a particular line of research will eventually benefit. Although the mechanism outlined in Option 6 provides a method for discovering medical technologies whose development is feasible, the unpredictability of basic research might make it preferable to withhold more formal assessments until actual technology development has begun, or until targeted developmental programs have been organized.

Option 7: Assessments could be restricted to medical technologies being developed through targeted programs. Technologies whose feasibility has been postulated, but whose development into a clinically useful form has not yet been attempted would not be candidates for assessment under this option.

Any formal program of technology assessment runs the risk of creating a large and expensive bureaucracy whose product may not be useful. Because technology assessment is a new field, this danger is increased. Because few medical technologies have been assessed, the usefulness of such assessments is difficult to predict (see ch. IV). One might prefer, therefore, to maintain the present system of evacuating social impacts and setting priorities until methods for technology assessment are more firmly established. The present system includes congressional hearings and the congressional appropriations process, decisionmaking in the executive branch, oversight by advisory committees at NIH, and judgment by institute staffs and study sections.

Option 8: Do not implement any formal programs of technology assessment at NIH.

A decision to maintain the status quo does not necessarily imply that technology assessment is not an important activity or that social impacts of new medical technologies should not be assessed. Option 8 could be adopted if it were felt that present methods of evaluation and assessment are adequate, that programs of

assessment should be implemented slowly and cautiously, or that NIH is not an appropriate institution to conduct or supervise programs of technology assessment.

TECHNOLOGY ASSESSMENT AT OTHER FEDERAL AGENCIES THAT SPONSOR BIOMEDICAL RESEARCH AND MEDICAL TECHNOLOGY DEVELOPMENT

Although perhaps the best known, NIH is not the only source of Federal Government funds for biomedical research and technology development. Other Federal organizations that support development and/or testing of new medical technologies include the National Science Foundation (NSF), the Veterans' Administration (VA), the Department of Defense (DOD), the National Aeronautics and Space Administration (NASA), and the Energy Research and Development Administration (ERDA) (see app. A). The administrative structures and responsibilities of these departments have not been examined during the course of this study. However, it seems reasonable to assume that programs of technology assessment, similar to those described above for NIH, could be implemented in some or all of these agencies.

Option 9: Programs of technology assessment could be implemented at some or all of the Federal institutions that support the development of new medical technologies. Programs would be similar to those outlined in Options 1 to 7 above, although their precise nature would depend on the structure and function of each agency or department.

TECHNOLOGY ASSESSMENT IN THE WHITE HOUSE OFFICE OF SCIENCE AND TECHNOLOGY POLICY

The programs specified in the options presented above would all involve technology assessment administered by organizations that conduct or support the development of medical technology. The assessments might be conducted either internally ("in-house") by staff members, or outside the Government, with grant or contract support. Assessments might focus on medical technologies being developed by the agency or department in question, or on technologies being developed in part or entirely elsewhere. In any case, however, assessments would be supported by organizations with a direct stake in the development of new medical technologies.

Such an arrangement has both advantages and disadvantages. One advantage is that assessments done by R&D organizations would have the best access to sources of technical expertise. Information about new developments or technical progress would be readily available and could be easily incorporated into each assessment. Questions could be asked with precision and the types of information that would be most useful could be specified. The results of each assessment could be used in making decisions that would modify the course of technology development in fairly subtle ways.

On the other hand, assessments done through agencies and departments that support technology development might raise problems of conflict of interest. These organizations have some reason to encourage further technology development and their assessments might reflect this bias. Furthermore, in cases where technology development is proceeding in several places, one agency might have difficulty in obtaining information from or making recommendations to other agencies.

Some of the disadvantages could be ameliorated, at the risk of losing some of the advantages, by performing assessments in or through a more central authority. A logical candidate is the Office of Science and Technology Policy in the White House, which was established by Public Law 94–282. This Office has the responsibility for furnishing the executive branch in general and the President in particular with advice on scientific and technological matters. One does not yet know how easy it will be for this Office to obtain information from agencies that fund medical technology development. By virtue of its central position, however, it might have access to many or all such agencies, and could take a broad view of new technologies and of their implications.

Option 10: Programs of technology assessment could be conducted or administered by the White House Office of Science and Technology Policy.

TECHNOLOGY ASSESSMENT IN THE DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

A number of offices and agencies in the Department of Health, Education, and Welfare (DHEW) that do not conductor support biomedical research are nevertheless involved in making policy related to the development and/or use of medical technologies. Some of these groups could conductor administer programs of medical technology assessment. Such an arrangement would share many of the advantages and disadvantages of programs of assessment at the Office of Science and Technology Policy (Option 10). It would, however, have the additional advantage that the assessments would be conducted in institutions concerned with areas that might benefit from the results of technology assessment. Groups in HEW have the responsibility for making decisions about biomedical R&D and technology development (for example, at NIH), and for making policies related to the introduction and use of new medical technologies in the service system (for example, through Medicare and Medicaid). Thus, assessments done in DHEW would be available to many agencies that might be interested in using their results.

Groups within HEW that might be considered as candidates for carrying out assessments include the National Center for Health Services Research (NCHSR), the Office of the Assistant Secretary for Health, and the Office of the Assistant Secretary for Planning and Evaluation. The Social Security Administration (SSA), which pays for the use of new medical technologies through the Medicare program, might also have an interest in conducting medical technology assessments.

Option 11: Programs of technology assessment could be conducted or administered by offices or agencies in DHEW that are not directly involved in supporting the development of new medical technologies.

TECHNOLOGY ASSESSMENT AND THE FOOD AND DRUG ADMINISTRATION

The options presented above deal primarily—although not exclusively—with the assessment of medical technologies being developed in the public sector or with public support. Many medical technologies, including a large number of drugs and devices are, however, developed largely or wholly in the private sector. (See ch. II for examples and discussion, and app. A for details.) Information about the

development of such technologies is considered proprietary and confidential, and thus might be inaccessible to many Federal departments or agencies.

Programs to assess some of these privately developed and marketed medical technologies could be administered by FDA. This agency has the power to require private corporations to submit information about safety and efficacy of new drugs. Under the recently enacted Public Law 94–295, this authority has been extended to cover medical devices. New drugs and some classes of medical devices must be approved by FDA as safe and effective before they can be marketed.

The requirements for certification could be expanded legislatively to include some form of social-impact assessment of new technologies that companies plan to market. The mandated assessment might, for example, be modeled on the environmental impact statements now required for some technologies. The companies themselves might be required to assess their products, or FDA could conduct the assessments.

This arrangement would have the advantage of providing a mechanism for assessing some-although not all-of the new medical technologies that are not developed in Federal programs. There are also drawbacks. One is that some technologies, such as surgical procedures, would still escape detection and assessment (see ch. II). Another is that manufacturers assessing or providing information about the products from which they hope to profit might be biased. Finally, it would be difficult for FDA to develop criteria to judge the results of an assessment. Unlike safety and efficacy, which can to some extent be quantified, social impacts are by nature nonquantitative, and necessarily involve prediction, speculation, and value judgment. Detailed protocols would be required to insure that appropriate standards are set and met.

Option 12: Some form of social-impact statement or technology assessment could be required as part of the procedure by which FDA approves certain new medical technologies for marketing and use.

APPENDICES

Appendix A

DEVELOPMENT AND DIFFUSION OF MEDICAL TECHNOLOGY

This appendix describes the process of development and diffusion of medical technology. It highlights five areas that are related to the concerns of this study, as described in chapter I.

- First, the activities that comprise the continuum from theory to practice are described and divided into four general categories: basic research, applied research and development, clinical testing, and diffusion and adoption.
- Second, the limitations of this or any other scheme of classifying R&D activities are discussed in order to make explicit problems that these limitations pose for policy makers and technology assessors.
- Third, some features unique to the development of each of the types of technology—techniques, drugs, equipment, and procedures-are enumerated.
- Fourth, some current mechanisms for funding and priority setting in biomedical R&D are examined. The role of NIH, the major Federal source of research funds, in setting priorities and allocating funds is reviewed briefly. The large investment in biomedical R&D in the private sector is described, along with the difficulties that this poses for comprehensive programs of technology assessment.
- Finally, the chapter examines evidence bearing on two converse concerns about lags in the development process—that some technologies are delayed in their development even after the necessary concepts and tools are available (so-called "bench-to-bedside" lags), while other technologies are widely adopted before they are completely developed and adequately tested.

THE PROCESS OF TECHNOLOGY DEVELOPMENT

Adoption of a new technology by the consumer can be viewed as the final step in a long sequence of activities (91, p. 64). First, a background or conceptual basis is laid by theoretical research and the sum of previous experience. Then, basic empirical research provides a framework of knowledge about the mechanisms involved, discovers points in a natural process that are susceptible to technological intervention, and suggests strategies for technological development. Applied or mission-oriented research is then directed at applying this basic knowledge to a practical purpose and demonstrating the feasibility of the proposed technology. Once feasibility 'is demonstrated, engineers, entrepreneurs, and developers, usually in the private sector, can develop goal-oriented programs. Prototypes are built and problems of transferring the technology from the laboratory to the marketplace are faced. Once the manufactured item is ready, its effectiveness and efficiency can be

assessed in a realistic way in industrial testing laboratories, in field tests, or in consultation with potential users. Finally, the technology is marketed and, if all goes well, it is adopted by the proper class of consumers, be they manufacturers or industries, public groups or institutions, or private individuals.

Such a sequence is attractive because it offers a way to understand the development process. For technologies of any type, however, this sequence represents a sociological ideal rather than a realistic description. Medical technologies, like other technologies, emerge from a process that is far less systematic than this model implies. Nevertheless, four general categories can be distinguished in the spectrum of activities that precedes the widespread acceptance of many medical innovations. They are: basic research, applied research and development, clinical testing, and diffusion (fig. 2).

Basic Research

Medical advance rests on a foundation of knowledge about the biological mechanisms that underlie the normal functioning of the human body and its malfunction in disease. This knowledge is acquired largely through basic biological research (3).

Lacking sophisticated tools, general theories, and the framework of the scientific method, early biologists were occupied with the enterprises of careful observation and extensive classification. Occasionally, general explanatory theories (for example, Darwin's theory of evolution or Harvey's theory of the circulation) emerged from the compilation of numerous observations. Most often, though, the early biologists amassed bodies of information that awaited further progress for their interpretation.

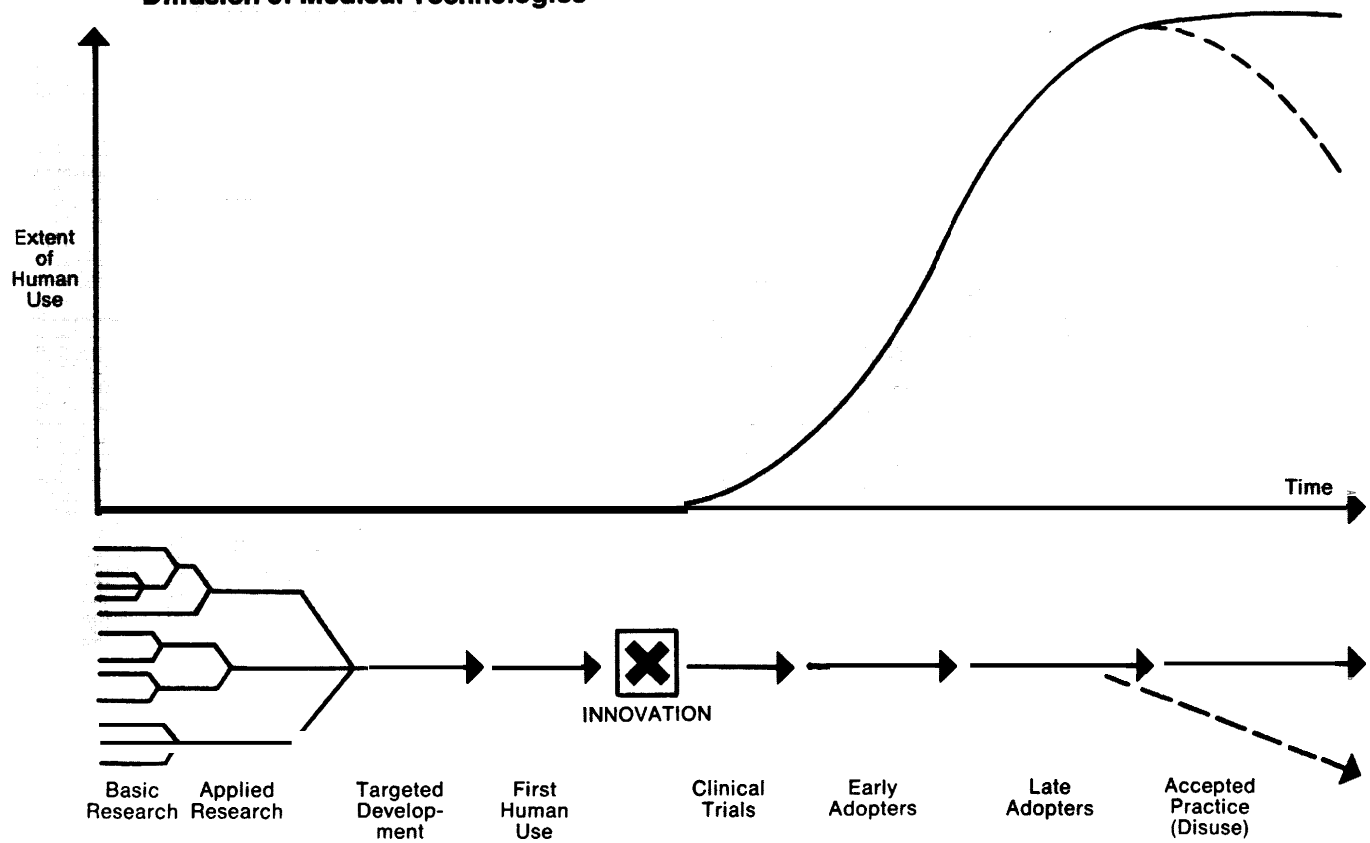
In the 20th century, biology has become a mature experimental science. Earlier detailed and reliable descriptions of whole animals or organs provided frameworks that have allowed the formulation and testing of hypotheses about the mechanisms that underlie a variety of previously described phenomena. The availability of new ideas and tools, derived largely from advances in the physical sciences, has made it possible for biologists to gain insight into many organic processes by focusing on smaller and smaller parts of the whole animal. Refinements in the techniques of microscopy and the later advent of electron microscopy have allowed examination of the cells from which tissues are built and of subcellular elements. The application of chemical theories and techniques to biological problems has made possible the study of the molecules and reactions from which all biological structures and functions are derived. The resulting progress, sometimes through spectacular breakthroughs but more often as a result of plodding, methodical work, has led to an understanding of the mechanisms that underlie a number of intuitively fascinating and practically important biological phenomena. Among the triumphs of modern biology are the discoveries of—

. The molecules and reactions responsible for the transmission of inherited characteristics from one generation to the next;

. The way in which chemical energy is transformed to mechanical energy to permit muscular contraction; and

. The ways in which large molecules called enzymes catalyze and regulate the chemical reactions that account for the body's metabolism.

Figure 3—**A Scheme for Development and Diffusion of Medical Technologies**



The promise of such basic research to the public is eventual advance in the prevention, diagnosis, and treatment of diseases. Fulfillment of this promise depends on the validity of two assumptions about basic research. First, biologists assume that knowledge acquired from studies of lower animals (which are readily available, provide numerous technically advantageous features, and can ethically be subjected to experimentation) will be applicable to humans. Second, they assume that knowledge about the normal functioning of the human body will lead to an understanding of the body's malfunction in disease. As biological knowledge has accumulated, these assumptions have been confirmed. Knowledge acquired through basic biological research has led to the development of effective and beneficial medical technologies. In some cases, such understanding has allowed the development of technologies such as vaccines, which prevent disease and make expensive, risky, and incompletely .effective treatment unnecessary.

The application of basic research findings to practical ends can occur in several ways. Frequently, the immediate connection is not clear, as when medical benefit is derived from the confluence of seemingly unrelated lines of research. 4

. The invention of the microscope, done out of curiosity, was one of the advances that made modern medicine possible.

. A long history of work on ways to grow living cells outside of the body led to development of cell cultures that were used to produce polio virus for vaccines. (See Case 3 in ch. II.)

In many other cases, logical progression from basic research to its applications can be discerned retrospectively, although application might not have been predictable in advance (264).

. Biochemical studies on metabolism led to the discovery of enzymes that regulate metabolic processes, then to studies of enzyme deficiencies in disease states, and finally to the use of enzyme assays as important diagnostic tools.

Occasionally, medical advance comes serendipitously from lines of biological research far removed from the particular medical area that benefits.

. The discovery of the Rh factor in blood, which led eventually to prevention of the fatal syndrome, erythroblastosis fetalis, resulted from work on variations in the color of butterfly and moth wings (45).

• The technique of freeze drying, now widely used to preserve antibiotics and blood fractions without loss of potency, was developed in studies on the water content of liver and muscle (45).

Finally, it must be noted that basic research in physics and chemistry, as well as in biology and biomedicine, can lead to medical advances. Sometimes the application is rapid, as when Roentgen discovered X-rays while he was studying the electrical nature of matter, and quickly applied his discovery to the examination of human tissue (45). More often, the physical sciences supply background, theories, techniques, and tools that are used for doing biological research or for applying biological knowledge to practical ends.

Applied Research and Development

In its *Forward Plan for Health,* DHEW defines "applied research and development" in biomedicine as "activity drawing upon basic information to create solutions to problems in prevention, treatment, or cure of disease" **(49).** While basic research in biology seeks to understand vital processes, applied research seeks their manipulation or control.

An illustration of the difference between basic and applied research is provided by the recent work of Bruce Ames and his collaborators at the University of California at Berkeley (119). For a number of years, Ames was engaged in studies on molecular biology. He created and used mutant strains of bacteria to study the mechanisms of genetic control of metabolic processes. This work was, by any definition, basic research. At some point, Ames realized that the information he and others had gathered about genetic mechanisms, and the bacterial mutants he had created, could be used to devise a system for determining whether particular chemicals could cause mutations. This information, he realized, would be valuable because other researchers had found that most carcinogenic chemicals are mutagenic. (In fact, chemicals may cause cancer by inducing mutations.) He therefore developed such an assay and has since used it to screen a wide variety of industrial and environmental compounds for potential carcinogenicity. Ames' application of knowledge gained through his earlier work to the practical end of developing a test for carcinogens is an example of applied research.

Similarly, each of the disciplines into which "basic" biological research is organized has an "applied" counterpart. The vitality of applied research varies, however, from field to field, depending on how well developed and solid the foundation of basic knowledge in each area is. Knowledge acquired through biochemical and physiological research has been applied to the development of many medical technologies, as the cases presented in chapter II illustrate. Ames' work on the application of molecular biology to practical ends is particularly noteworthy because the field of molecular biology is so new-the discipline has existed for only a few decades.

Although further application of recently acquired knowledge can be anticipated, it is a mistake to—

> attribute to biology and medicine a much greater store of usable information than actually exists. In real life, the biomedical sciences have not yet reached the stage of general applicability to disease mechanisms. In some respects we are like the physical sciences of the early twentieth century, booming along into new territory, but without an equivalent for the engineering of that time. It is possible that we are on the verge of developing a proper applied science, but it has to be said we don't have one yet (197, p. 116).

Much of the applied research that contributes to the development of medical technologies is not, strictly speaking, biological, but rather results from the application of knowledge derived from the physical sciences to the solution of biological problems. For example, chemical engineers are engaged in developing "biomaterials" that neither damage nor are damaged by the environment of the human body, and thus can be used in invasive medical procedures or for implants. The technology of electronics has provided instruments for measuring biological parameters, which have been adapted for diagnostic uses (see cases of continuous

flow-blood analyzer and computerized axial tomography in ch. II), as well as miniaturized power sources and control elements that are eventually used in therapeutic devices (see cases of cardiac pacemaker, cortical implants, and the implantable artificial heart). Organic chemists have developed techniques and strategies for synthesizing compounds that might be used as drugs.

Although applied research of these types is, by definition, goal oriented, the development of a particular new technology is not always the immediate goal. Applied researchers in both biological and physical sciences frequently concentrate on the development of new materials, tools, or techniques that they assume will be useful for a variety of applications.

The targeted development of a particular new technology begins when knowledge derived from basic and applied research is sufficient to support the effort. Although not without risks, both human and financial, the successful outcome can be predicted with some assurance, if solid foundation has been laid by prior research. As Thomas argues,

> When you are organized to apply knowledge, set up targets, produce a usable product, you require . . . certainty from the outset. All the facts on which you base protocols must be reasonably hard facts, with unambiguous meaning. The challenge is to plan the work and organize the workers so that it will come out precisely as predicted. . . . You need the intelligible basic facts to begin with (197, p. 118).

It must be emphasized, though, that the sources of these facts are many. Workers engaged in developing new technologies, whether they be biologists, engineers, or physicians, draw on knowledge gained through basic and applied research in biological and physical sciences alike, as well as on the rich lore of industrial, experimental, and clinical experience.

Clinical Testing

At some point in their development, new medical technologies must be tested in human subjects. This area of clinical investigation and testing encompasses a range of activities from first human use to large-scale clinical trials.

The nature of first human use varies with the technology being tested. To test many noninvasive procedures or equipment, the investigator may use himself or coworkers as subjects; little risk may be involved. In other cases, only small samples of blood or tissue may be required, and these can be obtained from a number of sources including blood banks and hospitals. For invasive or particularly risky procedures, however, careful medical supervision and considerable planning are required. Furthermore, in such cases, first human use raises problems of informed consent by the subject; the individual must be aware that he is participating in an experiment and must agree to become a subject (71). Recent policies have begun to bring these activities under the control of human experimentation committees at research institutions, which review all grant and contract proposals to NIH to help insure that basic ethical standards have been met (8, 147, 149, 151).

Occasionally, the first human use of a new technology is spectacularly successful (see the case of renal dialysis in ch. II). More often it is not, and modifications in the technology must be attempted. Clinical testing frequently reveals

problems that were not—and perhaps could not have been-anticipated from prior work on animals. In some cases, considerable further research is required; at other times, minor improvements prove to be sufficient. Therefore, continued development of new technology frequently continues apace with further clinical testing.

After a new technology appears to be useful in scattered clinical experiments, organized trials may be carried out; increasingly, these are controlled or randomized clinical trials. In such trials, the technology to be tested is applied to some patients and withheld from others. Patients in the "control" group, who do not receive the "experimental" treatment, are often given inactive substitutes or placebos, so that the psychological effects of "having someone do something" do not contaminate the trial's outcome. Patients are assigned to "experimental" or "control" groups by a randomizing procedure, and objective methods are devised for assessing the patients' conditions at predetermined intervals. Thus, the controlled trial at its best allows scientific evaluation of the efficacy of medical technologies.

Although the controlled clinical trial has been considered the *sine qua non* of effectiveness, some limitations in its methodology must be recognized. Controlled trials are expensive and difficult to organize. Years of trial may yield inconclusive results because the trial has not posed the proper question or used the proper methodology. (See the case of oral anticoagulants in ch. II.) Furthermore, the nature of the procedure or the seriousness of the medical problem it addresses may make organization of a controlled trial difficult. For example, a proper test of a new surgical procedure might require that some patients be given a "sham" operation; such "sham" operations may be risky to the patient and therfore raise serious ethical questions. In other cases, patients in "control" groups would be required to forgo treatments that are already available; this also raises ethical questions. In cases where no alternatives to the technology being tested are available, practitioners may feel that it is unethical to withhold a promising treatment from desperately ill patients. (See the case of radical mastectomy in ch. II.) Finally, if the natural history of a condition is well known, a controlled trial may not be necessary. (See the case of the cardiac pacemaker in ch. II.) Therefore, although the controlled clinical trial is a powerful tool, other methods for insuring efficacy are also important and necessary.

Diffusion and Adoption

The most important factors determining whether, or how rapidly, a physician will adopt a new technology are his own clinical experience and that of his colleagues (102, 183). Other sources of information, such as advertising campaigns, the technical literature, and programs of continuing education, are also important, but secondary in impact. Occasionally, if clinical trials of a new technology are promising, Government-supported demonstration projects are organized to show that a technology which is effective under controlled circumstances is also useful in the community, where socioeconomic and other factors may modify its impact (32, 152). In most cases, however, practitioners learn about new developments through less formal channels.

Although several sociological studies have examined the personal and demographic characteristics of early and late adopters of new medical technologies, comprehensive quantitative studies of diffusion in the medical area are few (80, 84, 103, 167, 173). Primarily as a result of extensive work in nonmedical areas, it has been found that the diffusion process usually describes an S-shaped or sigmoid curve, in which the rate of adoption accelerates as time goes on (171). Diffusion of some medical technologies follows this curve, as shown in figure 3A for adoption of intensive-care units by hospitals (47). The slower initial diffusion is often interpreted as indicating caution but is also consistent with poor communication between sellers and buyers or among buyers. Those who accept the new medical technology first are referred to as innovators, with early adopters and late adopters accounting for subsequent portions of the curve (171).

The diffusion of some medical technologies does not, however, follow the sigmoid curve. One major departure from the standard model occurs when diffusion reaches a high rate almost immediately after the technology becomes available, as shown in figure 3B for the case of chemotherapy for leukemia. This pattern has been referred to as the "desperation-reaction model" (209). A first phase of rapid diffusion seems to occur in the absence of evidence of efficacy because of the provider's responsibility to help a patient and their mutual desperation. Some-what later, results of clinical tests and experience begin to influence the physician's behavior. If results are positive, diffusion may continue rapidly. But if the evidence is not clear cut, there may be caution and slow diffusion. Finally, if the evidence seems to be negative, use of the technology gradually declines.

The "desperation-reaction" model points out a paradox in the diffusion of medical technologies. Faced with a desperate and sometimes life-threatening situation, each physician may be totally justified in adopting whatever technology is available. The aggregate behavior of many desperate physicians, however, may result in the extensive and premature diffusion of technologies that are incompletely developed, inefficacious, or possibly even dangerous.

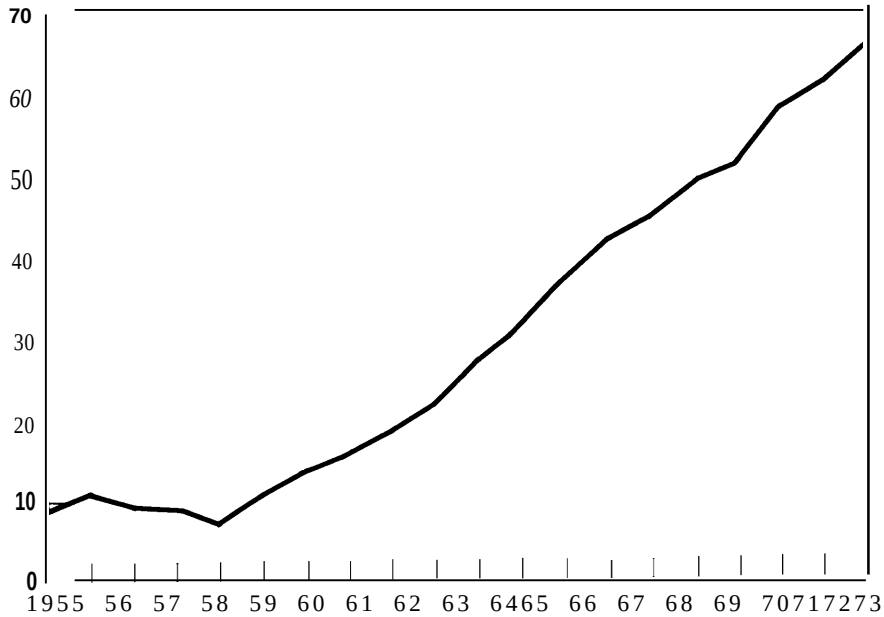
Whatever its initial pattern of diffusion, a technology may eventually be partially or completely abandoned. This can occur, as stated above, after a rapidly diffusing technology proves to be of little use clinically. Medicine is replete with examples of procedures that have fallen out of use, such as bleeding and cupping. More recent cases can also be cited. For example, a psychosurgical procedure called leucotomy or prefrontal lobotomy was widely adopted in the early 1950's and was later abandoned when its efficacy and safety were seriously challenged (fig. 3C).

A decrease in usage may also occur when a widely used technology is supplanted by one of greater efficacy or lower cost. Thomas et al. (198) have described this process for poliomyelitis, using the terms "high" and "halfway" technology. A high technology is the decisive, conclusively effective measure aimed directly at the underlying cause of the disease so that it can be terminated, reversed, or prevented. Prevention seems almost always to involve such "high" technology. "Halfway technology" refers to the measures taken to compensate for the destructive effects of diseases whose course cannot be altered, and whose biological bases are not fully understood. In the case of polio, a complex and costly halfway technology of rehabilitation centers and iron lungs was entirely supplanted almost overnight by the polio vaccine. (See the case of vaccines in ch. II.)

Figure 3—The Diffusion of Some Medical Technologies

A. Intensive Care Units

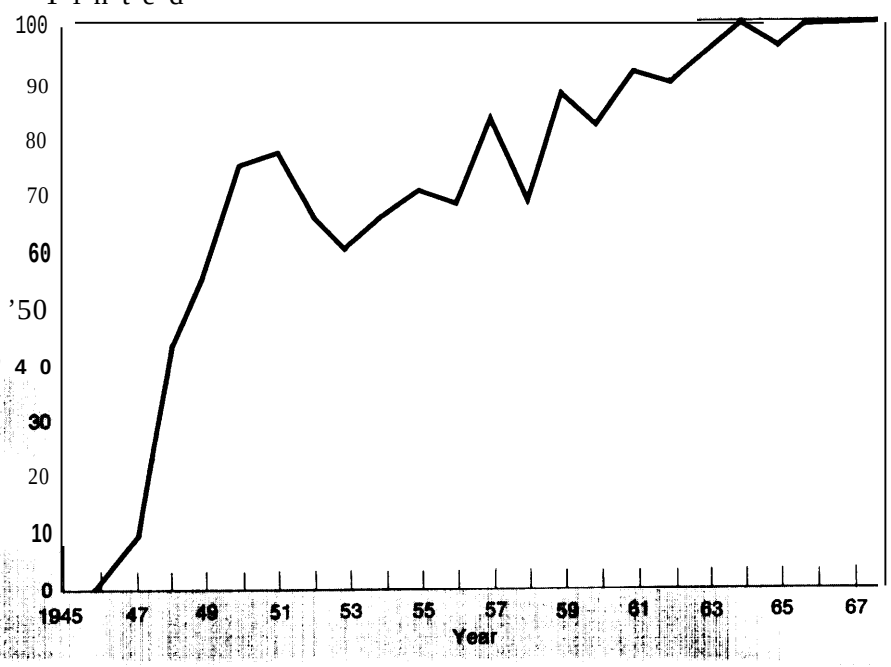
(% of Community Hospitals with Mixed ICU Units)



Source: Nnerlcen Ifosdtal Association.

B.

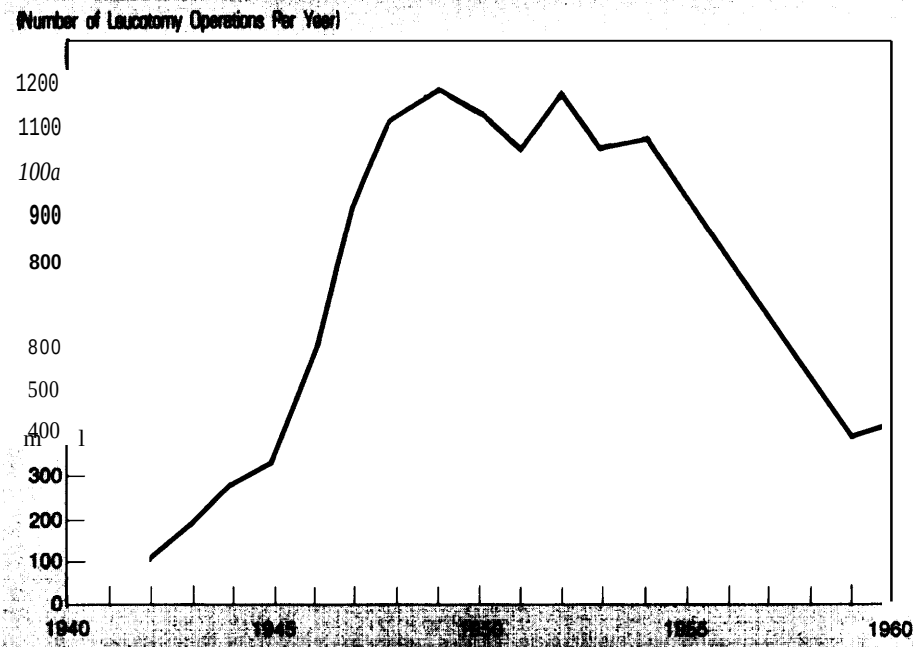
T i n t e d



Source: Reference 209.

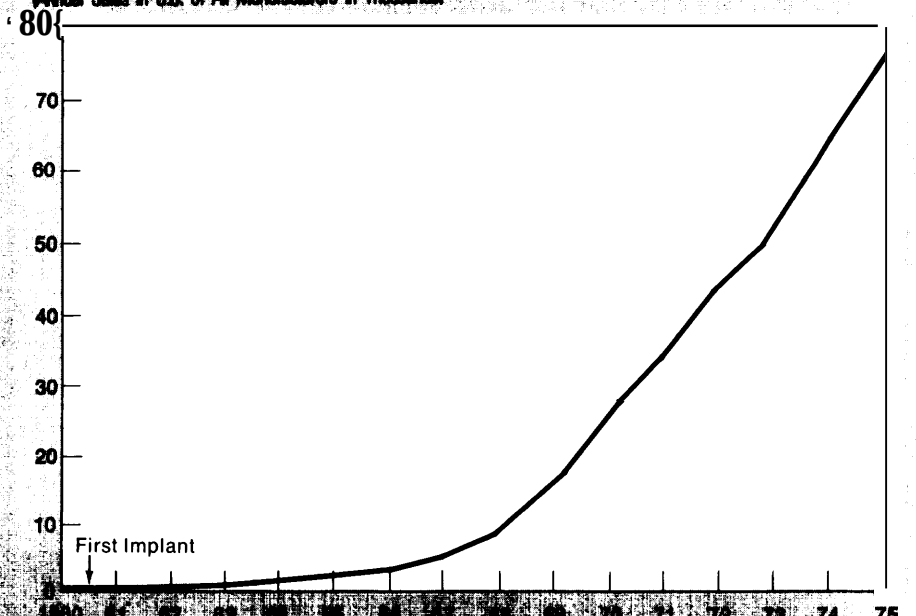
Figure 3 Continued

C. Leucotomy Operations (England and Wales)



Source: (1): G. Tooth and M. Newton, Leucotomy in England and Wales 1942-54, Reports on Public Health and Medical Subjects No. 104 (Ministry of Health, Great Britain: London, 1961).

D. Cardiac Pacemaker



Source: Medtronic Inc.

However, the ideal of high technology replacing halfway measures is seldom realized. Few things in medicine are as effective as polio vaccine, and prevailing technologies are regularly supplanted by somewhat more effective technologies. Furthermore, the society cannot wait for high technology to solve costly health problems, for research is slow and those threatened by diseases with unknown etiology may need expensive support systems.

COMPLEXITIES IN THE PROCESS OF TECHNOLOGY DEVELOPMENT

The categories distinguished in the previous section are adequate to classify a large number of the activities that precede widespread acceptance of a new medical technology. Categories similar to those presented here are commonly used in making decisions about resource allocation for biomedical R&D, establishing policies and priorities, and organizing institutional capabilities. It must be recognized, however, that such a classification scheme is highly idealized. If appropriate and effective programs of assessment are to be implemented, at least two severe limitations to the scheme must be considered:

First, the history of science and medicine shows that basic research, applied research, development, and even diffusion often progress simultaneously and not sequentially (29). Investigators approach the development of new technologies from many viewpoints and often independently; useful innovation most often results from the confluence of separate streams of basic, applied, and clinical research. Also, later steps in the process feed back on earlier ones—for example, new technologies may make new types of research possible, or clinical experience may suggest fruitful new research possibilities. Retrospective studies may discoverer even impose-a logical order that could not have been discerned while development was in progress. Thus, programs of assessment may aim for but not always achieve examination of the development of new medical technologies "at the earliest possible point."

Second, many programs of R&D cannot readily be fitted into one of the four categories discussed above. The boundaries between categories are indistinct, creating problems for attempting to understand the R&D process, and for attempting assessment or control. Although one can do little here to sharpen these boundaries, one can point out why and in what ways they are fuzzy.

Basic Versus Applied Research

Many types of research can easily be classified as basic, and others as applied, but there is a vast middle ground that. cannot be easily classified.

One problem in defining basic and applied research on biological systems can be illustrated by comparing biology with the physical sciences. Physics and chemistry are both sufficiently mature to support "theoretical" enterprises, which deal entirely with abstractions, usually mathematically.

Biological processes, on the other hand, have not yet been adequately described and cataloged in preparation for the creation of a firm, predictive theoretical base. This is not to say that biological principles of great generality have not been discovered; they have. With few exceptions, however, biologists are still experimentalists; they are not theoreticians.

Biology and the physical sciences differ at the other end of the R&D spectrum as well. Often, massive pieces of capital equipment are developed by engineers from a base of knowledge in chemistry and physics. Prototypes must be built in industrial laboratories and often require organization and resources on an industrial scale. Medical technologies are, however, usually small enough to be built with limited resources and by small groups of workers. Workable developmental models of most medical technologies can be created in the laboratory or at the medical center; pilot plants are seldom required. Development of medical technologies may of course be enormously expensive, but the physical scale is limited.

Thus, many research activities in the physical sciences are theoretical and therefore indisputably basic, or are industrial in scale and therefore clearly applied. In biology, nearly all research activities fall into a middle ground where classification is more difficult.

There are other problems of classification as well. Basic research is usually defined as an attempt to understand nature, while applied research is seen as an attempt to control nature. However, the aims of a particular project and its outcomes may be significantly different. Basic researchers sometimes acquire knowledge or devise techniques that have immediately applicable practical ends; applied researchers frequently make discoveries that lead to new understanding. Furthermore, the very concept of experimental science runs contrary to the distinction between understanding and control. Basic researchers must devise ways to manipulate nature if they are to perform experiments. The techniques they develop may have immediate practical as well as experimental utility.

Several attempts have been made to formulate characteristics that can adequately distinguish between basic and applied research. Lewis Thomas, for example, has claimed that "surprise is what makes the difference." He contends that basic research requires "a high degree of uncertainty; otherwise it isn't likely to be an important problem." Applied research, he feels, requires "a high degree of certainty from the outset" (197, p. 118). Although appealing, this distinction may not be practically useful. It does not completely describe either the basic researcher, who is not working in a vacuum and may be quite certain of what he hopes to achieve, or the applied researcher, whose activities are also creative, intellectually challenging and, in fact, sometimes quite uncertain.

Comroe and Dripps, in a study of the sources of knowledge that lead to medical innovation, make the distinction between "clinically oriented" and "nonclinically oriented" research (46). However, since funding agencies stress clinical relevance in their application forms, and since all biological research is potentially relevant, the purported orientation of a research project or publication does not seem to be practically useful in devising a meaningful distinction. A study by the Battelle Columbus Laboratories, with aims similar to the work of Comroe and Dripps, distinguishes between "mission-oriented" and "nonmission-oriented" research (10). This distinction, which is sometimes used by the NIH in describing its programs, is subject to the same caveats as that of Comroe and Dripps.

Thus, although many research programs can easily be classified as "basic" or "applied," there are some activities that defy categorization. This fuzzy line creates great problems for those contemplating assessment. On one hand, "basic" research can masquerade as "applied" research to compete for funding in an increasingly goal-oriented system; on the other hand, "applied" research can masquerade as

"basic" research to escape the pressures of social accountability that increase as one gets closer to practical application of knowledge.

Applied Research Versus Clinical Testing

Applied research performed in vitro (outside of the body) or using animals raises fundamentally different problems from clinical testing on humans, and different forms of assessment are appropriate for these two activities. Ideally, applied research and development of new medical technologies would depend on tests in animals, with clinical testing on humans occurring only when development is thought to be complete. However, some testing on humans is occasionally required well before a new technology has been completely developed. In some cases, work on animals cannot anticipate the special problems that human anatomy and physiology pose. In other cases, the uniquely human ability to respond verbally is required to assess the success of a new technology and to determine the directions that further developmental effort should take. Finally, some technologies are developed by practitioners who have patients available to them, but have neither the facilities nor the expertise for work on animals. For these reasons, activities of applied research and clinical testing are often inextricably linked.

Clinical Testing Versus Clinical Use

Finally, it is not even possible to separate the processes of research and development from those of diffusion and adoption when considering medical innovations. "Experimental" use of new technologies can involve rather extensive diffusion, and because this often occurs in university-affiliated medical centers to which physicians and the public look for guidance, such use can materially enhance pressure for widespread adoption. Also, scientific assessment of medical technology for safety and efficacy requires people, sometimes large populations. This rather wide diffusion before clinical proof inverts the expected order of testing and then diffusion.

The blurred distinction between development (or experimental use) and practice (or therapeutic use) is illustrated by the case of mitral valve surgery (192). The mitral valve of the heart can become constricted as a result of rheumatic fever. Brunton, a British cardiologist, proposed a surgical technique for reopening the valve in 1902. After preliminary tests on animals had been completed, surgery was carried out on 10 human patients between 1923 and 1928. Results were discouraging, and a period of 20 years elapsed before human use was again attempted and eventually proved successful.

As a result of this informal "clinical moratorium," the early trials can be classified retrospectively as "experimental," but the distinction was not clearly made at the time. It is often impossible to regard developing or newly developed procedures as either purely experimental or purely therapeutic. It is more realistic to think in terms of a process, with an experimental procedure at one end of a spectrum, a therapeutic procedure at the other end, and many steps in between.

A current example of this dilemma is the renal transplant, still hampered by problems of graft rejection. Research physicians acknowledge that renal grafting still provides a "fertile area for clinical investigation," meaning it is still experimental. On the other hand, transplants are gradually becoming clinically accepted and therefore more "therapy" than "experiment" (69, p. 73).

Presently, an informal evaluation by each physician is the primary method of classifying new procedures as "experimental" or "therapeutic." Of course, as indicated, there are many forces acting on the individual physician in making such a decision. In particular, one can highlight the "desperation-reaction model" discussed above: a clinical fervor to do something for desperately ill patients, at the same time producing a medical advance. Furthermore, some third-party payers will not reimburse for procedures that are designated as "experimental. " Formal criteria for distinguishing between experimental and therapeutic use have been proposed (106, p. 237) (114), but current medical practice does not permit a clear distinction in many cases.

DEVELOPMENT OF DIFFERENT TYPES OF MEDICAL TECHNOLOGY

Different types of medical technology are developed in different places and in different ways. These variations pose problems for assessors and must be considered if programs of assessment are to be realistic and effective. The following paragraphs describe some features unique to the development of the four categories of medical technology that were distinguished in chapter II: drugs, equipment, technique, and procedure.

Drugs

The link between basic biomedical research and drug development is often clear. Drugs develop from a basic knowledge of organic chemistry, pharmacology, and human pathophysiology. Occasionally, knowledge is sufficient to permit the rational design of new drugs. For example, the development of polio vaccines, which are classified as drugs for purposes of this report, was based on a solid foundation of knowledge derived from basic research. (See the case of vaccines inch. II.) Basic research in biochemistry and bacteriology has also permitted prediction of successful strategies for synthesizing some antibiotics. In many other cases, basic research has led to the development of new drugs even without complete knowledge of their mechanisms of action.

Some drug companies maintain institutes for and support work in biochemistry and pharmacology. However, much of the basic research that precedes the development of new drugs is supported by Federal agencies, especially NIH, and takes place in universities and medical centers. A study of 68 pharmaceutical innovations showed that over half were made possible by discoveries made outside of the drug industry, in universities, hospitals, and research institutes (129, p. 185). Although some applied research targeted to the development of new drugs is funded by NIH, most is supported by private industry.

Before marketing, new drugs must meet standards for safety and efficacy that are set and administered by the Food and Drug Administration. These regulations, mandated by the Food and Drug Act Amendments of 1962, constitute almost the only legal standards that new technologies must meet **(164). New** techniques and procedures are not at present similarly regulated. Some of the testing that precedes certification can be done on animals in the laboratory. Tests on human subjects are also required, and drug companies sponsor tests on volunteers in a variety of settings, including prisons. Ethical standards for clinical tests of drugs, long left largely to the discretion of developers, are currently being reviewed by the National Commission for the Protection of Human Subjects.

Once marketed, drugs are often accepted rapidly by practitioners, as seen in the adoption of new chemotherapeutic drugs for the treatment of leukemia (fig. 32?) (209). Adoption is speeded by a number of factors, including the low cost of drugs compared to many other technologies and the massive advertising campaigns frequently mounted by the pharmaceutical industry. A study of a new antibiotic showed that 60 percent of physicians had adopted it within 8 months of its release (39).

Equipment

Research in biomedical sciences such as physiology and anatomy provides knowledge that permits development of devices that can be used for diagnostic, preventive, and therapeutic purposes. However, much of the basic research that leads eventually to the development of equipment is performed outside the biomedical research sector in such fields as physics, chemistry, and electronics.

The successful development of equipment requires a combination of expertise in both the biological and the physical sciences. The application of the tools of mathematics and the physical sciences to biological and medical problems is called biomedical engineering (157). Biomedical engineers have achieved spectacular successes in recent years, but numerous difficulties beset their work. One is that most physicians are not trained to collaborate effectively with engineers to solve problems, or even to recognize that a technological solution might be feasible. Few individuals have sufficient training in both biology (or medicine) and engineering to work alone (82). Also, in a marketplace oriented to profits, medical equipment manufacturers may develop and overproduce equipment of questionable utility or fail to support the development of types of equipment that are needed (204). Additionally, engineers are trained to think in terms of physical performance characteristics and technical precision but often fail to evaluate new technologies on the basis of how they affect the health of populations or individuals. Finally, many feel that Federal health agencies are reluctant to fund private companies to do research or to develop new medical technologies that might return profits to those companies.

In the area of medical equipment, funding for applied research and development is largely private. There are some Federal programs to facilitate research and development of certain devices (94, 128). They are often fragmented, however, as shown by the complex pattern of Federal investment in the development of medical diagnostic ultrasound (table 1). Furthermore; it is frequently difficult to document these diverse sources of funds, and compilations such as that shown in table 1 are rare.

Once developed, medical equipment is tested in a variety of locales. Many items can be adequately tested in the laboratory, using healthy volunteers or small samples of blood or tissue. For equipment that is risky or requires invasive procedures for its operation, testing usually occurs in hospitals. Tests of safety or efficacy have not been legally required before new equipment can be marketed. However, the failure of some devices (76, 77) has led to the formulation of a medical devices bill that was recently enacted (P. L. 94–295) and will require premarket demonstrations of safety and efficacy for some medical devices (55, 56, 68).

Recent studies have begun to shed some light on how large pieces of capital equipment are acquired by hospitals. Diffusion may follow the S-shaped curve for

Table 1.—Funding for Research and Development in Ultrasonic Imaging Diagnostic Instrumentation by Federal Agency, 1975 (2)*

National Bureau of Standards	$100,000
Department of Defense:	
Army	120,000
Navy	285,535
Energy Research and Development Administration	80,000
Department of Health, Education, and Welfare:	
Food and Drug Administration.	841,459
Health Resources Administration	25,000
National institutes of Health:	
National Cancer Institute	418,514
National Heart and Lung Institute	2,851,165
National Institute of General Medical Sciences	1,530,166
National Institute of Arthritis, Metabolic and Digestive Diseases	118,964
National Eye Institute	439,297
National institute of Necrologic and Communicative Disorders and Stroke...	379,905
Division of Research Resources	20,000
Division of Research Services	50,000
Social and Rehabilitation Service	24,851
National Aeronautics and Space Administration	360,000
National Science Foundation	818,850
Veterans' Administration	20,500
Total	8,484,206

● Doesnot include all intramural programs, which are considerable.

some expensive technologies, as was the case for adoption of the intensive-care unit (fig_. 3A) (47). The large initial investment required may compel cautious adoption. On the other hand, there is evidence that hospitals may sometimes adopt large and highly visible types of equipment for purposes of prestige, without sufficient consideration of medical utility. Little is known about the diffusion of less costly types of equipment.

Technique

Medical techniques develop largely from knowledge gained through clinical experience. The spectrum of research and testing activities is difficult to separate. Testing for efficacy maybe minimal and informal. These developments depend on creative clinicians and probably encompass thousands of small incremental changes in medical practice, which diffuse in unstudied ways. There are special problems in assessing this part of medical practice because the steps in development and diffusion are so informal and ill-defined.

Procedure

A procedure is the combination of technique with drugs and/or equipment. Its development is correspondingly complex and depends on research and development in several different fields. The many bodies of knowledge and lines of research that led to the development of one complex procedure, cardiac pacemaker implantation, are indicated diagrammatically in chapter II (fig. 1).

New procedures are often tested in university-affiliated hospitals. Some tests are supported by Federal research funds and private funds. Considerable funding also comes from service funds (such as private insurance and Government financing programs), especially in cases where the distinction between experimental and therapeutic use is not clearly made. Some medical procedures have been submitted to formal clinical trial, but this is probably more common for new procedures than for existing ones.

There are presently few formal mechanisms to prevent unsafe and useless procedures from being used in medical practice (9, 17, 112, 130, 155). As noted, clinical trials are not often done. Hospital tissue committees, which screen operative results to assure that operations have been appropriately done, can sometimes assess the merits of new procedures, albeit in nonquantitative ways. Collegial standards and the growing threat of malpractice litigation provide strong but nonsystematic deterrents to the widespread use of procedures whose efficacy has not been demonstrated.

FUNDING AND PRIORITY SETTING FOR RESEARCH AND DEVELOPMENT

Biomedical research and the development of medical technology account for about 4 percent of the expenditures in the health area in the United States, or an estimated $4.5 billion per year (144). Federal obligations for health research and development were about $2.8 billion in 1974, or 62 percent of the total. State and local governments invest $284 million. The remaining $1.4 billion is derived from the private sector: $227 million emanates from private nonprofit agencies, and approximately $1.2 billion from industry. Sources of support for biomedical research and technology development are summarized in figure 4.

At the Federal Government level, the sources of health research support are myriad. Table 2 shows the Federal health research budget for 1975, indicating that the Department of Health, Education, and Welfare (HEW) controls more than 75 percent of the total, with the National Institutes of Health (NIH) predominant in HEW. NIH alone controls 63 percent of the Federal expenditure for health research.

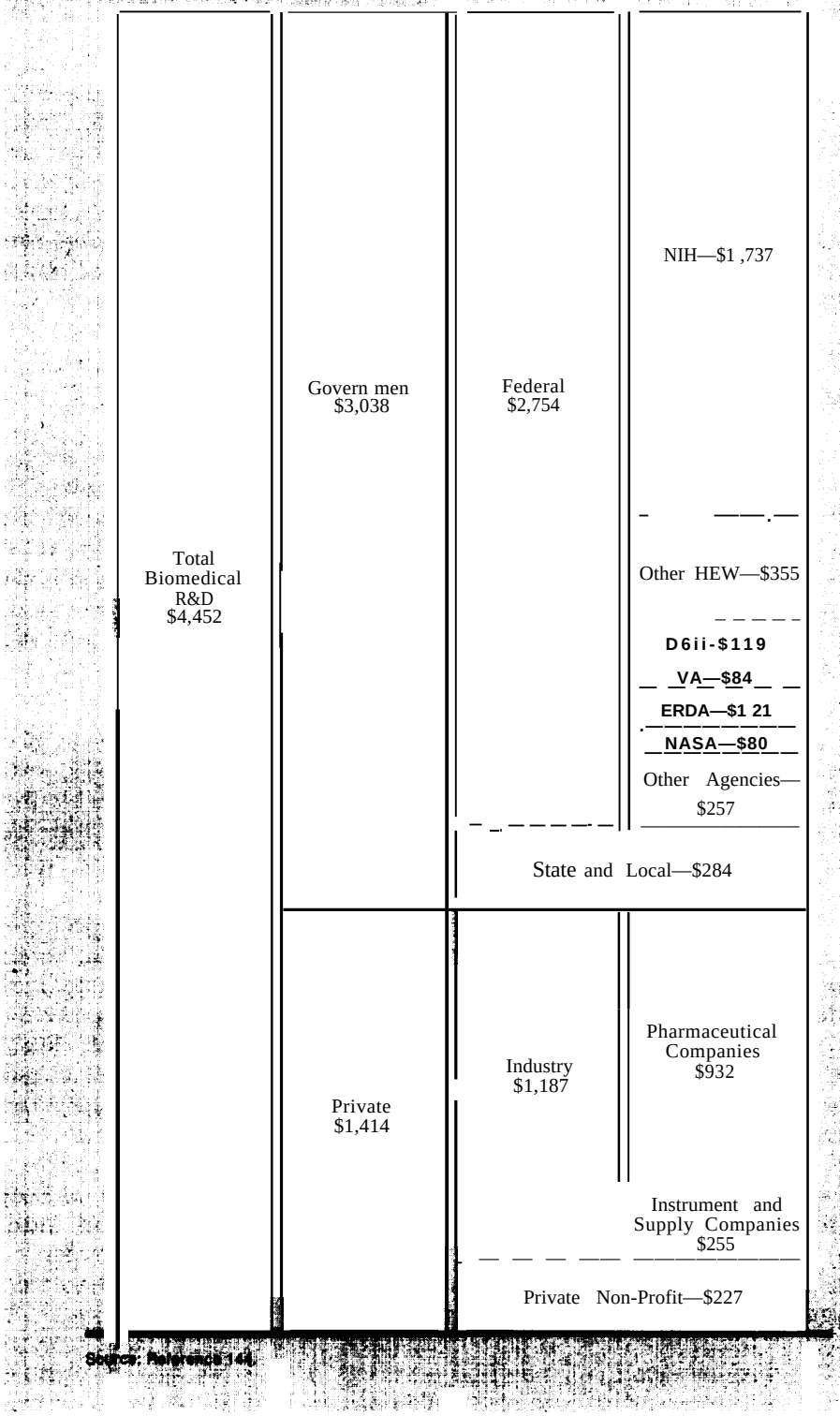
In the private sector, the industry figure includes $932 million invested by the 135 members of the Pharmaceutical Manufacturers Association, which includes some nondrug manufacturers (186, p. 26). An estimated 1,500 firms produce medical devices and instrumentation (55); companies manufacturing medical supplies and instruments invest an estimated $144 million in health R&D, and the electronics industry and the nonprescription drug industry invest an estimated $91 million in health R&D (144). The industry R&D is conducted largely “in-house” in research laboratories.

Basic research is largely funded by the Federal Government, although some is funded by private foundations, voluntary health agencies, and industry. Drug companies invest an estimated $90 million a year in basic research (186, p. 24). Other industries spend little on basic research (129, p. 20). A high percentage of the Federal investment in basic health research comes from NIH.

Applied research is funded by a variety of sources. Much of the support for applied research and technology development is derived from private industry.

Figure 4—[illegible]

(Millions of Dollars)



Source: Reference 144

Table 2.+ Federal Outlays for Health Research by Agency, 1975*

[Dollars in millions]

Department of Health, Education, and Welfare (total)		**$1,867**
Health Services Administration	9	
Health Resources Administration	58	
Alcohol, Drug Abuse, and Mental Health Administration	114	
Center for Disease Control	42	
National institutes of Health	1,598	
Food and Drug Administration	27	
Assistant Secretary for Health	4	
Social Security Administration	—	
Social and Rehabilitation Service	2	
Other HEW	13	
Department of Defense		**104**
Veterans Administration		**93**
Department of Housing and Urban Development		**—**
Department of Agriculture		**47**
Environmental Protection Agency		**20**
National Aeronautics and Space Administration		**59**
Energy Research and Development Administration		**143**
Department of Labor		**1**
Department of State		**—**
National Science Foundation		**44**
Department of the Interior		**35**
Department of Transportation		**15**
Department of Justice		**—**
Other agencies		**31**
Agency contributions to employee health funds		**—**
Total outlays for health, 1975		**2,459**

● **Because obligations and expenditures are calculated separately, the figures in this table differ somewhat from those in fig. 4.**

Source: **Table K-28 in** *Special Analyses, Budget of the Uniled States Government, 1977.* **Washington, D.C.: U.S. Governmen tPrintingOffice, 1976, p. 215.**

Most of the industrial R&D budget is spent on applied research and technology development with priorities usually determined by the perceived potential for profit (129, p.20).

Government investment in technology development is also considerable, although fragmented and largely undocumented. Research conducted or supported by Federal agencies such as NIH is often aimed directly at the development of new medical technologies. (See the case of the implantable artificial heart in ch. II.) Another important role of the Federal Government is in cooperation with private industry, through incentive or procurement programs. For example, the Veterans Administration and the Department of Commerce have been active in encouraging development through procurement programs (137). The National Science Foundation, in cooperation with the Veterans Administration and the Department of Commerce, has developed incentive programs. These programs generally are not coordinated among Federal agencies.

The mechanisms of NIH are organized to recognize the hazy line between basic and applied research. NIH's mission is to advance the health and well-being of man by—

- Enlarging knowledge and understanding of the normal and pathological processes of the human body; and
- Developing ways in which the providers of medical care can safely and effectively intervene to prevent, treat, or cure diseases and disabilities (146).

NIH has classically pursued this mission through supporting— "

- Biomedical research and development, including, in some instances, demonstration and control programs,
- Research training,
- Development of research resources, and
- Communication of research results (146).

These responsibilities are carried out through 11 categorical institutes, each of which awards grants and contracts, as well as carrying out "intramural" research (on the grounds of NIH).1 Each categorical institute is charged with supporting research aimed at eventual understanding and amelioration of a particular class of diseases.

Allocation of funds at NIH occurs at three levels:

1. From an overall budget, appropriations are made to each of the institutes. This is done by Congress: each institute is funded through separate appropriations.
2. Within each institute, funds are divided among various areas with competing claims to scientific, social, and medical importance. Each institute has a national advisory council, which is responsible for approving or disapproving grant awards and is supposed to consider such factors as potential importance of proposed research. Other decisions about allocation of funds within each institute are made by the administration of the institute, by the Director of NIH, and by Congress through special provisions in authorization or appropriation bills.
3. Awards are made to investigators or teams who compete for research funds. Funds are disbursed in the form of grants or contracts.

There are several important differences between grants and contracts. Grant proposals may be submitted on any topic that a researcher feels is relevant to the mission of NIH. The proposals are reviewed by 52 "study sections" at NIH, groups of outside scientists organized by discipline or scientific area. These study sections, or peer review groups, assess proposals for scientific merit, and assign them priority scores. The proposals are then referred to the appropriate institute, where the national advisory council ranks them, generally following closely the order determined by the study sections. NIH awards the funds based on this ranking. Grants may be awarded only to nonprofitmaking entities.

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[1]The National institute of General Medical Sciences has no intramural program.

Contracts are usually used for support of research and development when one or more of the following considerations exist (149):

- The awarding institute or division has identified a need for certain research work to accomplish its mission and has determined that the work must be done outside its own facilities. This is sometimes referred to as targeted research, and the philosophy is that the NIH staff should look at the field of biomedical science and target funds to areas that need further development or are ready for development. . .
- Funds are awarded to profitmaking institutions. Under current regulations, grants cannot be awarded to such organizations.
- The objective is the acquisition of a specified service or end product.
- The collaboration of a number of institutions must be obtained and work must be coordinated or carried out in a comparable manner by all so that the data collected can be combined for statistical analysis, such as in clinical trials.

Contracts are awarded at the initiative of the bureaus, institutes, divisions, the Clinical Center, and the Office of the Director of NIH. When a contract is to be awarded, a Request for Proposal (RFP) is developed by NIH staff based on a perceived need. These RFP's are published and distributed, and the proposals received are reviewed by special groups of outside scientists assembled for that purpose. National advisory councils usually are not involved in the awarding of contracts but are kept informed of contractual activities of the institute they serve. The awarding unit participates in the direction and control of the contracted work to the degree necessary to accomplish its mission.

In 1974, $765 million was distributed by NIH in the form of regular grants, $335 million as contracts, and $246 million as center grants (144). About 10 percent of the NIH budget supported the intramural research program. The Director of NIH has estimated that 27 percent of NIH dollars supports basic research (70).

Clinical testing is funded by a variety of sources. Private industries, particularly drug companies, sponsor a large amount of clinical testing of new technologies, including some formal clinical trials. Federal agencies also support clinical testing. In **1974,** for example, NIH supported 1,080 clinical trials at a cost of approximately $168 million; 65 percent of these were controlled trials (148). NIH also supports testing of new technologies through grants to medical centers in which clinical testing is a major activity. For example, NIH now funds centers in which heart transplants are carried out. NIH also funds significant demonstration and control programs in communities around the Nation, especially in cancer control and heart disease control.

Some clinical testing is also supported by service funds—that is, money appropriated for health-care delivery. For example, an insurance company may not cover a procedure that is clearly experimental (such as a heart transplant), but it will pay for the use of the operating room or for the cost of hospitalization. Furthermore, some technologies that are in fact being developed or tested are not formally classified as experimental and are thus eligible for reimbursement from insurance companies or Federal programs such as Medicare.

The present pattern of support for biomedical R&D raises several problem~ that must be considered if developing medical technologies are to be properly

assessed. First, Federal support for biomedical R&D is administered through a bewildering variety of agencies. Compilation of the budgets and agenda of these agencies, a formidable task, is a necessary prerequisite to comprehensive programs of assessment. More information about the effect of Federal programs on private investment is needed if the results of assessment are to be useful. As discussed in a report prepared by the Rand Corp. (29), Government funds administered in different ways can encourage, discourage, or displace private investment in R&D. If assessment of Government programs results in altered allocations, the effects of these alterations on industrial expenditure must be considered. Finally, most of the targeted development of medical technology currently proceeds in the private sector, supported by industry, and motivated by the quest for profit (129, p. 20). Programs of assessment aimed specifically at Federal agencies will inevitably be incomplete.

LENGTH OF TIME FOR THE DEVELOPMENT AND DIFFUSION PROCESS

There are, inevitably, lags between the time when an idea or innovation is conceived and the time when a technology is introduced into practice. The lag should be neither too short nor too long. If too short, it may be that the technology was not completely developed or tested before it was introduced. If too long, patients who might benefit might be needlessly deprived of appropriate therapy.

On the question of long lags, Peltzman (164) has calculated the costs that would have accrued had appropriate therapies for tuberculosis (antibiotics) and mental illness (tranquilizers), and preventive measures for polio (vaccine) been delayed for 2 years. The purely monetary costs, in terms of lost productivity, would range in the billions of dollars; social or human costs are incalculable. Although no detailed analysis has appeared, one might imagine that costs of premature introduction of inefficacious therapies are also enormous.

Unfortunately, there is no reason to think that lags could be shortened appreciably without sacrificing caution. Comroe (44) and a study by Battelle Columbus Laboratories (10, 11) have calculated duration of lags in development of 186 innovations and have analyzed reasons for those lags. In both studies, median lags from "conception" to availability were 10 years or less.

In another study, lags from discovery to innovation were compared for various nonmedical technologies and pharmaceutical innovations. While all technologies had lags averaging 14 years, and technologies in the petroleum industry had lags that averaged 11 years, new drugs were introduced only 5±4 (mean ± standard deviation) years after the time of the discovery that made innovation possible (129, p. 181).

In most cases studied, reasons for long lags were limitations of knowledge or lack of supporting technology. This seems to indicate that the lag has been wrongly defined, since the application was impossible for scientific technical reasons. For example, Battelle considers that there was a long lag between conception and clinical application of the idea of kidney transplantation. However, immunosuppressive therapy, a necessary prerequisite to clinical success, was not available until shortly before human kidney transplants were attempted. Apparent lags can also result from delayed adoption of available techniques. Studies of the quality of

medical care indicate that the most appropriate diagnostic or therapeutic procedures are often not used in medical practice; however, these cannot properly be considered lags.

One cause for lags pointed out by Comroe and by Battelle is a failure of communication: loss and subsequent rediscovery of important ideas, resistance to innovation by uninformed physicians, or academic skepticism to challenging new ideas. Some ameliorative measures might be applied in this area.

The Overview Cluster of the President's Biomedical Research Panel (198) has also examined the question of whether excessively long lags have occurred. Examining a representative list of the therapeutic and diagnostic advances of the past 25 years, the report concludes that the progress from discovery to application appears to have occurred in a reasonably timely and orderly fashion. This does not mean that in some cases lags might not have been shortened by applied research or targeted programs, but evidence that this might be true is lacking.

On the other hand, there is the question of lags that are too short. There are great social, economic, and human costs attached to prematurely accepting technology. In the present medical system, development and testing are often not completed before a new technology is introduced; examination of social impacts is almost never done.

The reason for this lies in the present system of health-care delivery (29, 72, 83, 208). The medical market is not a free market, with private consumers buying from those willing to supply the technology at the market price. In fact, there are numerous deviations from the free-market model. There are few sellers of either service or technology and many barriers to entry in the form of educational requirements and licensing. Regulation of firms, which is increasing, is another barrier to entry. Sellers, especially physicians, cooperate with each other and do not compete for the lowest price. The public is ignorant of what is available and is unlikely to become educated, given the unclear goals of the system and the complexity of medical care. Physicians also have no incentive to hold down costs in a system where almost the entire population has insurance coverage for hospitalization and surgery. Externalities such as controlling epidemics or improving the economy complicate the medical market further. And finally, the position of the physician is remarkable. The hospital administrators depend on his expertise and follow his advice in purchasing. He also makes most of the decisions for the patient, especially when these involve expensive diagnostic or therapeutic procedures. The physician, trained to deal with crises and to be instrumental, wants to provide everything possible for his patient (195).

These features of the medical market all combine to produce incentives for premature acceptance of incompletely developed or tested technologies. Premature acceptance may have occurred in such cases as radical mastectomy and anticoagulants for myocardial infarction (see ch. II).

Thus, attempts at assessing the development of biomedical R&D must take account both of the possibility that some medical technologies are delayed in their development and the certainty that other technologies are diffused prematurely, before they are completely developed (84). It must be recognized that many of the "pressures for premature acceptance arise in the health service system and therefore that assessment of R&D, while undeniably important, may fail to deal with many of the fundamental problems that motivate this report.

Appendix B

METHOD OF THE STUDY

The general process for studies in the Office of Technology Assessment (OTA) is to have an advisory panel of experts for the study. Panel members suggest source materials and experts; assist in data collection and interpretation; review staff drafts for accuracy and validity; suggest conclusions based on the facts; suggest options for the consideration of Congress; and give arguments for and against specific options. However, the panel does not determine the content of the report and is not responsible for the conclusions and options.

Such a panel was formed for the study on biomedical research and development of medical technology. Dr. Eugene Stead was selected as panel chairman. Other panel members were then selected with the help of Dr. Stead to represent a wide range of disciplines, viewpoints, and expertise. Two members of the Health Program Advisory Committee, who had expressed particular interest in this study, were made members of the panel.

The first meeting of the Panel on Biomedical Research and Medical Technology was convened in Washington, D. C., on January 23, 1976. At this meeting, the Panel discussed the scope of the study. In addition, the Panel endorsed the use of specific cases of development and diffusion of medical technology to illustrate some general points, as well as the complexities of the process. Specific cases were recommended by the Panel for inclusion in the final report, and the points illustrated by each case were discussed.

Between the first and second meetings of the Panel, the staff initiated discussions with selected individuals and groups, including:

Office of the Assistant Secretary of Health, Department of Health, Education, and Welfare
Office of the Assistant Secretary for Planning and Evaluation, Department of Health, Education, and Welfare
The Director and other officials, National Institutes of Health, Department of Health, Education, and Welfare
Officials of the National Center for Health Services Research, Department of Health, Education, and Welfare
Officials of the Food and Drug Administration, Department of Health, Education, and Welfare
Officials of the Office of Research and Statistics, Social Security Administration, Department of Health, Education, and Welfare
The President's Biomedical Research Panel
The Commission for the Protection of Human Subjects
Officials of the National Science Foundation
Staff of the Institute of Medicine, National Academy of Sciences

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Some **voluntary associations were also contacted and gave informal assistance.** In particular, the American Association of Bioanalysts and the American College of Radiology were helpful in furnishing factual information about their respective fields.

At the second meeting of the Panel on February 23, a draft outline developed by the staff for the final report was presented and discussed. There was also more general discussion of the complexities of the charge and of the field under study. Some possible conclusions and options began to emerge from the discussion.

Between the second and third meetings, the staff reviewed materials relating to the subject, received copious materials from certain Panel members, and developed drafts of chapter IV ("A Framework for Medical Technology Assessment") and chapter V ("Findings and Options"). Ms. Sherry Arnstein of the National Center for Health Services Research and Dr. Robert Ringler, Deputy Director of the National Heart and Lung Institute of the National Institutes of Health, were particularly helpful in suggesting references and reacting to drafts of these chapters.

At the third Panel meeting on March 16, three guests made comments and answered questions from the Panel and staff: Dr. Donald Fredrickson, Director of the National Institutes of Health; Dr. Clifton Gaus, Director of Health Insurance Studies for the Social Security Administration; and Dr. Robert Ringler, Deputy Director of the National Heart and Lung Institute and staff to the NIH Totally Implantable Artificial Heart Assessment PaneI. These witnesses were very helpful in suggesting ways technology assessment or other types of assessment could help the process of biomedical research and development of medical technology. The remainder of the meeting was used to discuss conclusions of the study and policy options to be presented.

Between the third and final meetings, the staff continued to collect materials, including helpful comments from Panel members, and completed a draft of the report. At the final meeting of the Panel on March 31, an essentially complete draft report was presented and discussed. The Panel reviewed the report page by page and made many helpful comments and criticisms.

A revised draft was then prepared and submitted to the OTA Board. The Board approved release of the report, subject to final editing and revision, at its meeting of April 13. The draft was then sent to members of the Technology Assessment Advisory Council, the Health Program Advisory Committee, and the Advisory Panel to this study, and to approximately 40 interested individuals both within and outside of the Federal Government, including officials at NIH. During May and June, the staff considered a variety of comments and criticisms received from these people, and prepared a final version of this report for publication.

Although members of the Advisory Panel had enormous impact on the report, the staff takes full responsibility for its contents. Indeed, several Panel members object strenuously to some of the policy options, and inclusion of an option should in no way be construed as indicating approval of the Panel for that option.

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