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Allocating resources among AIDS research strategies

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Abstract. One of the central questions facing policy-makers is how to allocate limited federal funds among alternative AIDS research strategies. A rational answer requires judgments about both the prospects of scientific progress and the societal value of research outcomes. Using a decision-analytic approach, this paper examines the marginal returns from additional funding of basic biology, epidemiology and mathematical modeling, vaccine development and testing, treatment development and testing, and behavioral and social science. A survey of a recent Institute of Medicine Committee on AIDS was conducted to elicit scientific judgments on the prospects for scientific progress in each of the five areas. The scientists were quite capable of transcending their disciplinary orientation as reflected in the dominant sentiment in favor of more behavioral and social science research. A comparison of the actual FY 1987 AIDS research budget with the budgets recommended by the scientific experts also suggests that basic biological research deserves greater emphasis.

Since the first cases of acquired immunodeficiency syndrome (AIDS) were reported in the United States in mid-1981, over 84,000 cases have been reported to the Centers fro Disease Control. Another 1 to 1.5 million Americans are believed to be infected by the human immunodeficiency virus (HIV). The Public Health Service projects that 65,000 Americans will die of AIDS in 1992 alone (Public Health Service 1988).

In addressing the numerous public policy issues raised by an epidemic of such proportions, policy-makers have relied heavily on experts in scientific fields related to AIDS research. Experts have contributed to policy discussions on such diverse questions as the financing of AIDS treatment, confidentially of test results, and implementation of contact tracing. A less publicized but similarly critical class of issues surrounds the direction of research policy by the federal government. Since relatively little is known today about what behavioral, vaccine, or therapeutic strategies will be effective, research is a key component of the national effort to conquer AIDS.

In the area of research policy, expert advice at the level of resource alloca-

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tion is particularly important. Traditional resource allocation methods may overlook new research strategies of critical importance. Areas with little established infrastructure or funding may require a concerted federal effort – including appropriate incentives to individuals and institutions – for their timely development. Scientists involved with AIDS research are best acquainted with the progress of research, best able to identify gaps in current efforts, and best able to determine where funds should be directed to achieve desired results.

In this analysis, we are concerned with the ability of policy-makers to obtain policy-relevant information from experts. Policy-makers need information relevant to deciding an annual budget. In providing testimony or working on commissions, experts often define overall priorities, from which policy-makers attempt to deduce appropriate incremental allocations. In addition, experts may compromise in order to present a 'consensus' view to policy-makers, actually obscuring specific areas of agreement and disagreement among scientists.

The purpose of this study is to demonstrate a systematic method of identifying areas of research which should receive priority in funding, making greater use of expert knowledge. We begin with a set of assumed societal goals for research related to AIDS. These could represent, for example, objectives identified through the political process or developed by a commission on national priorities for addressing the AIDS epidemic. We then demonstrate a method for eliciting the assessments of scientists and other experts in fields related to AIDS research in a form relevant to a resource allocation decision. These expert assessments can be used to inform the decision of how to distribute available funding to various research areas to best achieve the identified societal goals. We seek a resource allocation plan which successfully incorporates the advice and judgement of those most knowledgeable about the progress and potential of AIDS research.

Methodology

The literature on expert judgment for policy-making generally recognizes that the role of the expert in this context is not to make the decision, but to contribute to the basis upon which the decision is made. As Turoff notes, 'A policy issue is one for which there are no experts, only informed advocates and referees... The decision-maker is not interested in having a group generate his decision; but rather, have an informed group present all the options and supporting evidence for his consideration.' (Turoff 1975). As argued by the National Research Council's Committee on Risk and Decision Making, a model of 'policy made by scientists and professional analysts... is both unattainable and incompatible with democratic principles.' (National Research Council 1982). The Committee argues that policy decisions usually involve conflicts of interest which, according to democratic ideals, should be worked out through the political process.

The role of the expert is then to inform policy decisions, or, as Turoff suggests, to advocate for effectiveness and efficiency. Distinguishing between the proper role of experts and that of policymakers, however, does not assist policy-makers with the practical problem of how to obtain the appropriate contributions from experts. This paper demonstrates a strategy for eliciting from experts the technical information relevant for a resource allocation decision.

Strategies for obtaining multiple-expert opinion range from non-interactive polling arrangements to highly interactive processes (Morgan, Henrion and Morris 1979). A major advantage of interactive methods, such as Delphi techniques, is the learning process which occurs among participants. Several disadvantages are associated with group processes, however, including the domination of discussion by outspoken personalities and reluctance to express unpopular opinions. For our investigation, we conducted personal interviews with participating experts. Several studies support the use of non-interactive techniques where consensus is not a main objective (Morgan, Henrion and Morris 1979). In addition, the experts we contacted had already participated in extensive group discussions on the subject of AIDS research, and had thus accrued some of the educational benefits of interaction. Finally, the practical difficulties of reconvening this group of experts made a personal interview method most feasible.

Description of participating experts

Relevant expertise, while not the only criterion, is generally the primary consideration for selecting participants for Delphi and other multiple-expert processes (Graham, Hawkins and Roberts 1988). For this project, we defined relevant expertise to include breadth of knowledge across areas of AIDS research, as well as depth of knowledge in one or more areas. Breadth holds particular importance because the necessity of trade-offs in resource allocation decisions inevitably requires comparison across investment alternatives.

The experts participating in this project were members of the Committee on a National Strategy for AIDS, a group assembled in 1986 by the National Academy of Sciences' Institute of Medicine to study the current status of research related to AIDS. The report of this committee, published in late 1986, reviewed the status of research in diverse fields, and highlighted areas

Table 1. Areas of expertise; self-assessment by participants.

Research categories	Rank frequencies*		
	1	1 or 2	4 or 5
Biology	8	8	3
Treatment development & testing	2	4	4
Vaccine development & testing	1	5	4
Social & behavioral research	3	3	8
Epidemiology & mathematical modeling	2	6	7

* A rank of 1 means that this is the participant's area of greatest expertise. A rank of 5 indicates the area of least expertise.

in urgent need of attention. The report also recommended an increase in federal outlays for AIDS research from a projected FY 1988 level of $471 million to $1 billion in 1990, a suggestion which has guided much recent policy discussion (Institute of Medicine 1986).

The Institute of Medicine Committee represented a group of nationally recognized experts with a wide range of research interests relevant to AIDS (Appendix A) and a diversity of professional experience and expertise (Table 1). Although the committee did not deal with resource allocation in their formal recommendations, the members did, through their involvement with the Committee, accumulate information as well as a broad perspective on AIDS research. This group thus seemed a particularly suitable one to provide policy-relevant information concerning resource allocation. We invited all members of the Steering Committee and the Research Panel of the Institute of Medicine Committee on a National Strategy for AIDS to participate in this study. Seventeen of the 19 members approached agreed to be interviewed.

Interviewing framework

Our objective in interviewing the Institute of Medicine committee members was to elicit assessments of where AIDS research funds should be allocated to be most effective in achieving a set of societal goals. As noted earlier, a primary consideration was to divorce value judgments as to the appropriateness of such goals – the province of the decision-maker – from evaluations of effectiveness and efficiency of research. We therefore specified a set of three goals which we asked experts to accept as being equally desirable to society. The method for determining these goals is described below. We then composed questions designed to assess the relative contribution of investments in five research areas to achieving any of these societal goals.

Specification of societal goals

Our specification of societal values was based on a set of normative assumptions, operationalized using a model of the AIDS epidemic. We first assumed that AIDS-related knowledge was sought by society only for its contribution to the realization of three intervention strategies:

- Acceleration of vaccine availability;
- Acceleration of development of new treatments;
- Reduction in the incidence of infection through behavior change.

We assume, for example, that 'spillover benefits' to other areas of scientific inquiry are not a decisive justification for investing in a particular area of AIDS research.

Second, we assume that society's principal goal is to minimize the number of life years lost due to AIDS. This assumption implies, among other things, that life years saved through treatment are equal in value to life years saved through prevention. Such an assumption could be debated: lives saved or prolonged through prevention are healthy lives, whereas treatment prolongs lives affected by a debilitating illness. Societal preferences, however, often reflect the appeal of identifiable cases, making the superiority of preventive measures less clear.

Finally, we assume that society is equally competent at implementing each type of intervention – behavioral prevention, vaccines and treatment. No consideration is therefore given to practical impediments such as ethical issues surrounding vaccine testing, or public resistance to implementing educational programs. As a decomposition strategy would suggest, we assume that such issues would be confronted at the next level of decision-making.

The three intervention strategies are operationalized as the following research outcomes, estimated to be of equal value to society:

1. Reducing the time until a vaccine is available for large-scale production by one year (Base Year 1995).
2. Reducing the time until an effective treatment is available by one year (Base Year 1995).
3. Developing a behavioral prevention program that, if fully implemented by 1990, would achieve a 20% reduction in the average annual probability that an uninfected person becomes seropositive (Base Year 1986).

Equivalence of these outcomes was determined using a model of the AIDS epidemic (Appendix B). These three research outcomes would result in the same number of life years saved by the year 2005, according to simulations of the epidemic using this model.

To achieve one or more of these outcomes, experts could recommend investment in any of five categories of AIDS-related research:

- Basic Biological Research[1]
- Vaccine Development and Testing
- Treatment Development and Testing
- Epidemiology and Mathematical Modeling
- Social and Behavioral Research

While AIDS research does not always fit precisely into one of these groups, these categories correspond generally to those used by the by the National Task Force on AIDS and to the categories used by the Public Health Service to classify their AIDS research budget. Table 2 shows how federal monies have been allocated among these categories during fiscal years 1984 to 1986. In fiscal years 1984 and 1985, for example, the majority of federal AIDS research funds were expended on epidemiology and biology. In fiscal year 1986, treatment-related research began to receive the largest allocation.

Basis for allocation: marginal returns to research

To determine whether the priorities reflected in the AIDS research budget correspond to current knowledge of the progress of research, we developed a procedure that would allow us to compare the 'marginal returns' to society of funding more research in each of the five research categories. Economic theory argues that it is the output of the last or 'marginal' dollar which is relevant for resource allocation decisions. Resources should be allocated so that the marginal investment in one category of research brings the same benefit as the last dollars invested in other types. This allocation constitutes an efficient use of resources – it obtains the largest possible benefit for a given amount of funds.[2]

Conceptually, the marginal value of a research investment can be divided into two components: the contribution of the investment toward attaining specific research outcomes, and the value to society of those outcomes. The value of this knowledge to society depends upon factors related to the manner in which society would choose to use the knowledge generated. These values are assumed to be reflected in the three research outcomes, as noted above. The focus of our inquiry was thus on the effectiveness of research investments in attaining the three research outcomes.

The expected gain in knowledge from a marginal investment depends on the current state of knowledge and the promise of research already in progress. The cost and availability of scientists with the required skills, interests, facilities, and talents to undertake new projects are critical determinants of what a marginal investment can purchase. Finally, the intrinsic difficulty of obtaining the desired knowledge is an important consideration. All of these

Table 2. Trends in AIDS research funding. U.S. Public Health Service, FY 1982 to FY 1987

	Federal funds allocated to AIDS research by research category (in millions of dollars)						
	1982	1983	1984	1985	1986	1987	Total
Treatment development	n/a	n/a	8.73	11.95	57.36	108.21	186.25
Vaccine development	n/a	n/a	2.90	10.19	18.02	32.61	63.71
Epidemiology	n/a	n/a	19.60	26.50	38.70	68.70	153.50
Social & behavioral	n/a	n/a	1.11	1.56	1.59	4.34	8.59
Biological research	n/a	n/a	22.21	29.61	39.74	63.99	155.56
Total, 5 categories	n/a	n/a	54.54	79.80	155.41	277.85	567.61
Total allocation	5.56	28.74	61.46	109.62	233.81	415.81	820.47

	Percentage distribution of AIDS research funds				
	1984	1985	1986	1987	Average
Treatment development	16%	15%	37%	39%	33%
Vaccine development	5%	13%	12%	12%	11%
Epidemiology	36%	33%	25%	25%	27%
Social & behavioral	2%	2%	1%	2%	2%
Biological research	41%	37%	26%	23%	27%

Figures for research by category are not available for 1982 and 1983.
Total allocation figures include funds for Public Health Control and Patient Care in addition to the research categories.
Total allocation for 1987 includes a new $23 milion Multidisciplinary Research category. All 1987 figures are projected amounts.

Source: Public Affairs Office of the Office of the Assistant Secretary of Health. Included are AIDS research funds allocated to the PHS, which includes CDC, NIH, FDA, ADAMHA, and HRSA. Funding categories corresponding to above categories are:

Therapeutics
Vaccines
Epidemiology
Psychosocial Factors
Pathogenesis and Clinical Manifestations

(This category originally included Epidemiology and Psychosocial Factors, which were transferred to separate categories, and Surveillance, which was eliminated as a non-research item. Remaining in this category are virology, immunologic studies, etiologic studies, and Simian AIDS.)

factors are best estimated by experts intimately familiar with the relevant research areas.

Content of the interview

Our strategy for eliciting evaluations of the marginal returns to research was to ask participating experts a series of questions, described below, requiring them to allocate funds to the five research areas. Investment in a research area was to be preferred if it contributed more to achieving one or more of the three research outcomes than an investment in some other area. Again, we emphasized to the participants that their recommendations should not reflect their evaluation of the overall value of a particular strategy, but should assume only that the three research outcomes were of equal value to society. While it would be difficult for experts to ascertain minor differences in research productivity through this process, we expected experts generally to agree where clear advantages or disadvantages existed for investing in some of these areas.

The final component of our interview is a sensitivity analysis. This analysis is included in recognition of the uncertainties contained in our simulation of the future of the AIDS epidemic. In addition, reasonable people can dispute whether the outcomes we derived are in fact of equal value to society. We therefore performed sensitivity analysis by changing one of the three research outcomes such that this outcome is more difficult to attain, and exploring the effect of this change on expert choices.

Reallocation of existing funds

In order to determine whether funding for AIDS research was allocated properly to the five research categories, we asked each expert to consider a reallocation of $10 milion within the total research budget, projected to be $278 million for FY 1987. In particular, we asked the expert to specify both a category that should give up $10 million and a category to receive an additional $10 million. We asked experts to choose the category to receive the $10 million based on the contribution the additional funds would make toward accomplishing the three research outcomes described above. Similarly, the category chosen to lose $10 million was to be chosen on the basis of the least disruption in progress toward achieving the three research outcomes. If the actual allocation to the five areas were optimal, then we hypothesized that experts would recommend against any transfer of $10 million. Experts who chose to transfer $10 million were asked to provide an explicit rationale for their choices.

Allocation of additional research funds

After the 10 million 'transfer' questions were finished, we asked each expert to assume that this reallocation was actually implemented. Then each expert was asked to choose the research category that would benefit most from an additional $50 million in FY 1987. As with the $10 million, the extra $50 million was to be allocated on the basis of forecasted progress in achieving the specified research outcomes. Experts were not permitted to divide the extra $50 million among two or more categories. Once again, we asked for an explicit rationale for each expert's choice. After the first choice was elicited, we also asked the experts to indicate their second, third, fourth and fifth choices in order of preference.

Answers to the $10 million and $50 million question were intended to provide an indication of where experts believed additional dollars would do the most good. We also elicited expert opinion about how the entire FY 1988 AIDS research budget should be allocated. Since the size of the FY 1988 budget had not been determined at the time of our interviews, we asked experts to assume that they had $500 million to allocate among the five categories of research. Once again, allocations were to be recommended with the desired research outcomes in mind. The actual FY 1988 AIDS budget for research turned out to be $514 million.

Results of expert interviews

Fifteen of the 17 participating scientists expressed an opinion on the $10 million transfer question. The results are summarized in Table 3. All of the scientists elected to adjust the projected FY 1987 allocation. Nine of the fif-

Table 3. Responses to $10 million reallocation question.

Categories	Number of experts choosing a category to:	
	Receive the reallocated $10 million	Lose the reallocated $10 milion
Biology	2.5*	0
Treatment D & T	0	4
Vaccine D & T	3.5*	1.5*
Social & behavioral	9	0
Epidemiology & math. mod.	0	9.5
Total	15	15

* The choices of experts who were indifferent about which of two areas should receive or lose the $10 million are reflected by half votes to each area named.

teen believed that social and behavioral research should receive the transferred $10 million. While vaccine development and biological research were preferred by some scientists, none chose to transfer $10 million to either treatment development or epidemiology.

Participating scientists were generally very reluctant to cut $10 million from any of the five categories. Indeed, the group was convinced that the funding available in each area was probably too small. When compelled to choose a category for redistribution, some convergence of opinion did emerge. Two-thirds of the participants felt that the least harm would be done by reducing funding for epidemiology.

When asked which category should receive an additional $50 million, 16 of the 17 scientists were willing to express an opinion. Their first choices, reported in Table 4, do not convey much convergence. While there was no support for allocating the $50 million to epidemiology, each of the other four categories was the first choice of two or more experts. The most popular choice, biological research, did not command a majority of the 16 respondents.

The responses to the $50 million allocation question are somewhat more revealing when the rankings of the preferred research areas are considered (Table 4). Vaccine and biology were consistently ranked as a first or second choice to receive the new $50 million, and were the categories least often ranked fourth or fifth. The reverse was true of epidemiology, which was never

Table 4. Responses to $50 million allocation question.

Categories	First Choices	Rank frequencies*		Rank freq of 1 or 2, adjusted for expertise**
		1 or 2	4 or 5	
Biology	7	10	2	6
Treatment D & T	2	2	10	2
Vaccine D & T	3	10	5	10
Social & behavioral	4	8	8	6
Epidemiology & math. mod.	0	1	13	1
Total	16	31	38	25

* Not all experts provided a complete ranking of the five categories. Omitted categories were assigned equal ranks, at the center of the range omitted. For example, if an expert ranked only a first and second choice, the remaining categories were given a rank of 4. For this reason, these columns do not sum to 32.

** Rankings of 1 or 2, with rank of 1 eliminated if in expert's area of self-assessed strongest expertise. This column thus reduces bias toward expert' own field, but also discounts some experts' knowledge of their own area.

ranked first and most frequently ranked last. Treatment also appeared most frequently in the lower rankings. Social and behavioral research received the most polarized rankings, with rankings being split evenly between low and high numbers.

The right hand column of Table 4 adjusts the rankings by subtracting rankings of '1' assigned to an expert's self-assessed strongest area of expertise. This column reduces the effect of expert bias toward his or her own field, although at the same time it discounts certain experts' knowledge of their own area. Subtracting these rankings highlights the importance given to vaccine development. Otherwise, it does not change significantly the priorities indicated by the experts. More notable is that only six first-place rankings were given in participants' own area of expertise, and that these were all in the two categories which received the highest total first-place rankings. Experts appear to have largely transcended the natural bias or sympathy they may have toward the needs and value of work in their own area.

Results of sensitivity analysis

Experts' responses to the $50 million allocation question were consistently insensitive to changes in the specification of the three research outcomes assumed to be of equal value to society. Details of the sensitivity analysis are available upon request from the authors. There are several possible explanations for this result. The first is the conceptual difficulty of the comparisons required in the sensitivity analysis itself. This difficulty was certainly a factor, as was apparent in several interviews. Alternatively, some participants' initial answers may reflect holistic considerations rather than the marginal considerations intended. Some experts may have been unable – despite effort – to accept the assumptions presented, or found it difficult to differentiate marginal value from the overall promise of a research area. Finally, expert choices may indeed have been insensitive to the changes in outcome specification in the sensitivity analysis. We believe that all three of these explanations are valid to some extent – a reflection of the heterogeneity of the group in terms of familiarity with and interest in this type of analysis.

Rationale for answers to allocation questions

The reasons expressed for the choices in both questions painted a rather consistent picture, and raised a number of issues regarding the current allocation of AIDS research funds. Social and behavioral research received disproportionate support in the $10 million reallocation question because of the frequently expressed opinion that such research had a strong potential to contribute, especially in the short run, and was notably underfunded. Several of the experts were mistrustful of research in the social sciences. Of this group, some chose to fund social scientists anyway, apparently because of the large disparity they saw in funding. While these individuals commented on the 'abysmal' quality of current behavioral sciences research, they felt that an infusion of funding could promote improved quality. Others who commented on the underfunding of social and behavioral research believed that additional funds would not be well used, and should not be allocated. Several experts felt that social and behavioral research was so dramatically underfunded as to warrant the full infusion of $50 million. Most, however, felt that such a large amount would be more productively invested in biology or vaccine.

Epidemiology was selected by no one to receive either a $10 million reallocation or $50 million of new funding. Most experts expressed the view that while epidemiologic studies had contributed greatly to the understanding of AIDS thus far, quality studies were already being funded, and additional funds would not contribute significantly to further understanding. As one committee member commented,

> I think that epidemiology has given us plenty to work with for the next few years. It seems to me that we already know a good deal about the existing groups at highest risk; we know a good deal about the mechanism of transmission. So I would say, of areas of research that are less likely to yield in those three outcomes, it's less likely to do so.

Another member commented similarly,

> I would say that the gains of epidemiology are mainly in, and the gains for many of the other areas are yet to come. So I don't want to denigrate epidemiology, I just think that in terms of the epidemiology we've learned maybe 90 percent of what we're going to learn, and now it's going to be very expensive to learn another 10 percent.

Vaccine development, while sometimes chosen to receive the $10 million reallocation, was also occasionally chosen to lose it. For the $50 million, it appeared to be a greater priority for funding. Still, most of the experts giving vaccine development a high ranking ranked it as a second choice rather than first. Most experts' reservations about investing in this area concerned the marginal usefulness of the funding given the current progress in vaccine research. A frequent comment of those who gave this area a low priority ranking was that most of the work which could be funded in vaccine development was already being funded:

> I'm not sure that by putting more money into vaccines you're going to make that move ahead any faster, because all the really good vaccine

people are already involved...

> It looks like vaccine research is underfunded, but I'm not sure you could spend it well in terms of what's being done now. It's the one program that should have the highest priority in the long run. Vaccine testing and development is time-intensive, and putting a lot more people to work on it is not going to speed it up that much.

At least one expert felt that while $10 million would contribute little to the vaccine effort, a $50 million addition would underwrite substantial progress in the research:

> People would look at all of the other [vaccine] strategies, not just those that appear to be the most likely to succeed commercially. Ten million probably is not enough, but 50 million would be a really big hit in that area.

Treatment development was an area of clear expert consensus in considering a $10 million allocation. No experts chose to transfer $10 million to the area, while five chose to take the funds from treatment development. Those subtracting the funds from the area frequently expressed the opinion that investments in biology were more likely to lead to attainment of an effective treatment than were funds targeted to treatment development.

> Most of the treatment is very empirical and unlikely to really lead to major breakthroughs. More dramatic breakthroughs leading to effective treatments may come out of the biologic reseach. The biggest expense item is treatment and much of that is testing in a relatively blind way of anything on the shelves. The likelihood of that having a major impact early is not great.

> I think they've got the cart before the horse. They need to know more biology before they do the [treatment] research.

Others were skeptical about the possibility of developing a treatment:

> My assumption is that a treatment will never be fully effective for this kind of virus infection. At best it's going to be suppressive. It's possible but unlikely that antiviral therapy will be radically effective in the way that a vaccine is.

Several experts expressed concerns about the cost-effectiveness of current efforts in treatment research:

> There is the real risk that we are going to put too much federal money into treatment modalities. They're very expensive. Specifically, I [worry about] bypassing ordinary peer review. I think that's dangerous in terms of the use of the money.
>
> It's a very expensive area relative to the others. The amount of money in the federal budget put into treatment development and testing – it's kind of an inefficient way to spend money. It's not nice to talk about treatment of sick people as inefficient, but an awful lot of money goes into one study of one drug.

Two experts, however, chose to invest $50 million in the treatment development area. These experts expressed the view that although development of a therapy was not imminent, treatment development was the only outcome that was at all likely to be attained:

> There will be a lot of problems developing [a vaccine], because the unique nature of this virus doesn't lend itself to that very easily. One is going to be mighty lucky to find such a vaccine. The other thing is, how do you test such a vaccine?... I think the only hope is going to come in finding a therapy, and it may be that there will be a variety of therapies.
>
> Until we get the vaccine completely developed, the only other area that's going to impact [on AIDS] significantly is treatment.

The area of basic biological research was chosen to receive the $10 million reallocation by only three experts. Perhaps more importantly, however, no expert chose to subtract funds from that area. Biological research was the category chosen most frequently by experts to receive the new $50 million, and it received the fewest low rankings (only one) in this question.

The reasons given for allocating the $50 million to biological research centered around the longer term contributions of this research in achieving the treatment and vaccine development outcomes.

> There are so many fundamental phenomenon connected with the behavior of the virus, how it enters the cell, what it does after it's inside, and why it periodically emerges... If we understood that then I think it would give us handles on the other things.

Related to this idea was the role of biological research in highlighting new approaches to accomplishing the outcomes. These notions reflected a sense that current knowledge was not a sufficient foundation for further applied work, and that the most important aspect of biological research would be its identification of new approaches.

> Most of the [applied] programs are well encompassed in terms of current ideas. The greatest payoff is from speculation at this point. What you want is the unthought of. You want the next generation of ideas, and that's going to come out of biologic research.

> It's so broad and so untargeted that maybe a shotgun approach to one or more of those targets might really pay off.

Allocation of the FY 1988 budget

Perhaps the most revealing exercise is to compare the allocation of AIDS research funding recommended by the experts to the current and projected patterns of distribution. The experts examined Table 2 as they gave their recommendations, so their choices are made in reference to the projected FY 1987 allocations, and in view of the funding levels from 1984 through 1986.

The range of percentage responses given by the experts include the actual percentage allocation for four of the five categories. The glaring exception is social and behavioral research. This category receives 2 percent of the projected FY 1987 budget, compared to recommended allocations ranging from 5 to 30 percent (median 10 percent). Some scrutiny of Table 5 reveals less obvious discrepancies between expert opinion and the projected FY 1987 allocations. The Institute of Medicine group saw relatively more promise in biological research and vaccine development and testing, and relatively less promise in the categories of treatment development and testing and epidemiology and mathematical modeling.

Unfortunately, changes in the Public Health System accounting system make direct comparisons of the expert recommendations with actual FY 1987 or FY 1988 allocations difficult. While specific categorization of research in four areas is still available, the Public Health Service (PHS) no longer separately identifies social and behavioral research.

While the total amount of funding allocated to AIDS research in FY 1987 was about $40 million more than projected, the distribution of funds in the four identified categories did not change greatly, even though social and behavioral research is now subsumed in one or more of the other four research categories (Table 5). All four categories are within 2 or 3 percent of the projected FY 1987 levels, and the same pattern of divergence from the mean expert allocations remains. The projected FY 1988 figures indicate two changes, a decrease in the proportion of funding allocated to treatment and a substantial increase in the relative funding for epidemiology. The projected treatment development and testing figure of $175 million, while an absolute

Table 5. Responses to $500 million allocation question (in percent).

Research categories	Mean expert allocation	Range	Reference:* projected FY 1987 allocation	Actual FY 1987 allocation	Projected FY 1988 allocation
Biology	32%	20–50%	23%	26%	23%
Treatment D & T	26	5–40	39	41	34
Vaccine D & T	18	10–25	12	10	12
Social & behavioral	13	5–30	2	**	**
Epidemiology & M M	11	5–25	25	23	31

* Participating experts were provided with projected FY 1987 figures. Their choices are thus made in reference to these projected levels of allocation.
** As noted in the text, comparable figures for behavioral and social sciences are not available after FY 1986.

increase of $46 million, represents a 7 percent decrease in treatment research as a proportion of reseach funding. This decrease is consistent with the recommendations of the Institute of Medicine experts.

The projected increase in funding for epidemiologic research, in contrast, conflicts markedly with expert recommendations. Funding for epidemiology is projected to increase to $160 million in FY 1988 from $71 million in FY 1987, a dramatic increase in both absolute and proportional spending. While the epidemiology category may contain part or all of the funding for social and behavioral research, it is unlikely that this area, funded at $4 million in FY 1987, could be responsible for a major part of the $89 million increase.

Funding levels for social and behavioral research may well have increased in FY 1987 and FY 1988. Much of the research in this category is conducted by the National Institute for Mental Health (NIMH), National Institute on Alcoholism and Alcohol Abuse (NIAAA), and National Institute on Drug Abuse (NIDA). Funding to these agencies is reflected in the Alcohol, Drug Abuse, and Mental Health Administration (ADAMHA) budget, which has been increasing rapidly. However, this budget includes funding for prevention activities such as education and testing, as well as for AIDS research in all five categories. In previous years, when social and behavioral research represented 2 percent, 2 percent, and 1 percent of the funds allocated to the five research categories, the ADAMHA budget represented 5 percent, 2 percent and 5 percent of total AIDS funding, respectively. The ADAMHA budget for FY 1987 increased to 9 percent of the PHS AIDS budget, and in FY 1988 it is projected to be 12 percent. If the increased proportion of the AIDS budget appropriated to ADAMHA is associated with an increase in funding of social and behavioral research, then the budget has moved in the direction recommended by experts. This evidence is, of course, very speculative. The fact that social and behavioral research is no longer identified as a separate category may be a more revealing indicator of the priority of research in this area.

Conclusions

Resource allocation decisions, such as that of how to distribute funds for AIDS-related research, require more than global assessments of the various research categories. They also require information concerning the productivity of investment alternatives at the margin. While the former type of information is often obtained from experts through the political process, we have argued that the latter type can and should also be obtained from scientific experts. In this study, we found that a systematic decomposition of the issues implicit in resource allocation facilitates the formulation of questions useful for a marginal analysis.

Although accustomed to thinking in more global terms, experts were able to separate assessments of the progress and potential of research from factors such as the feasibility of interventions and value to society of research outcomes. Furthermore, experts were able to transcend a purely disciplinary orientation in their recommendations. Their choices point to investments in areas of research which were underrepresented on the committee. These recommendations proved largely, although not entirely, insensitive to the area of expertise of those recommending. We believe that their shared experience on the Institute of Medicine Committee contributed to a broad perspective on the promise of AIDS research.

This undertaking enabled us to take advantage of a substantial convergence of expert opinion regarding the marginal returns to AIDS research. This convergence extended beyond that reflected, for example, in the Institute of Medicine recommendations regarding AIDS research. Specifically, experts clearly believe that research in the areas of biology and social and behavioral sciences should be prioritized for new funding although, in the latter case, consensus disappears beyond the $10 million level. Equally clearly, epidemiology is considered the most adequately funded area at the current time.

The willingness to spend $10 million on social and behavioral research and the reluctance to spend more in part reflects concerns about how much the field can absorb, given that current spending is only about $5 million. In addition, this disagreement reflects some divergence in the respondents views about whether large funding increases constitute ‘throwing money at the problem,’ or whether such increases send a needed signal demonstrating a serious commitment by the federal government.

Biological and behavioral research, the two areas most strongly recommended for support at the margin, share a common 'basic research' orientation. The productivity of this type of research is more complicated to evaluate than that of research in applied areas such as treatment and vaccine development. While the anticipated outcome of applied research is clearly defined, basic research in biology and the social and behavioral sciences is not directed toward a single intervention strategy. Respondents to our survey thus confronted a two-step analysis in evaluating research in these areas, first considering what possible outcomes could result from this research, and second, assessing the likelihood that these outcomes would be achieved. In both research areas, the respondents seemed to think that valuable outcomes were possible. In the social and behavioral sciences, however, they questioned whether research of this type was of adequate quality to achieve these results.

In our view, expert opinion obtained through a process of decomposition contains clear messages regarding resource allocation which are not available to policy-makers through less explicit means. Expert recommendations diverge in important ways from the allocation of resources resulting from the political process. These expert assessments reflect the experience and intuition of individuals with considerable knowledge about AIDS research. They are directed toward policy-relevant questions. We believe this type of information can contribute importantly to resource allocation decisions.

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Notes

1. We define 'basic' to be research without an immediately foreseen application in prevention or treatment.
2. The logic is that allocation decisons made on the basis of the overall value of a strategy instead of the margin (e.g. placing all available resources into vaccine development because it is the *best* strategy) may actually waste resources. If vaccine development projects are prioritized and the best ones funded, then funding another set of lower priority projects in this area will, at some point, be less productive than funding top priority projects in some other research data. This argument assumes that there are not significant economies of scale in AIDS research.

Appendix A

Participating experts

Members of the Steering Committee and Research Panel of the Committee on a National Strategy for AIDS

David Baltimore	Whitehead Institute for Biomedical Research Cambridge, MA
John J. Burns	Roche Institute of Molecular Biology Nutley, NJ
Leon Eisenberg	Harvard Medical School Boston, MA
Bernard N. Fields	Harvard Medical School Boston, MA
Harvey V. Fineberg	Harvard School of Public Health Boston, MA
Jerome E. Groopman	Harvard Medical School Boston, MA
Maurice R. Hilleman	Merck Institute for Therapeutic Research Merck Sharp & Dohme Research Labs, West Point, PA
Richard T. Johnson	John Hopkins University School of Medicine Baltimore, MD
Robert F. Murray, Jr.	Howard University College of Medicine Washington, D.C.
June E. Osborn	School of Public Health University of Michigan Ann Arbor, MI
Roland K. Robins	Molecular Research Institute and ICN Pharmeceuticals Costa Mesa, CA
Margery W. Shaw	University of Texas Health Science Center Houston, TX
P. Fredrick Sparling	University of North Carolina School of Medicine Chapel Hill, NC
Cladd E. Stevens	New York Blood Center New York City, NY
Paul Volberding	San Francisco General Hospital San Francisco, CA
Irving Weissman	Stanford University School of Medicine Palo Alto, CA
Sheldon M. Wolff	Tufts University School of Medicine and New England Medical Center Boston, MA

The following persons were also members of the steering committee or research panel, but dit not participate in this study:

Frank Lilly	Albert Einstein College of Medicine Bronx, NY
Howard M. Temin	University of Wisconsin School of Medicine Madison, WI

Appendix B

Calculation of outcome equivalents

In order to develop the statements about the equivalence of the three research outcomes given to the scientific experts, we developed a simple model of the HIV/AIDS epidemic. The model is not intended to give accurate forecasts of the future number of HIV infections or AIDS cases; we believe that this is impossible with current knowledge. Rather, the model is intended to show the relative effects of three generic sorts of interventions. Based on our investigations, we believe that the relative effects we estimate are reasonably robust over the range of parameter values that fit current data.

Our calculations involve two implicit assumptions:

1. When calculating the benefits of behavioral prevention or a vaccine, we measure the public health impact of an intervention in terms of the total number of people infected with the AIDS virus. When calculating the benefits of a treatment method, we consider impact on the number of case-years of frank AIDS. Specifically, we use the number of new infections and case-years over the period 1988 to 2005. Because so much will change between now and 2005, we felt that going beyond that date was not reasonable.
2. We assume that a vaccine that prevents the transmission of AIDS and a treatment modality capable of keeping patients free from the effects of AIDS for life will become available by 1995, with the current level of research effort. This defines the base from which the relative benefits will be estimated.

The projection model

The projection model assumes that there are three groups in the population. At time t, let

S_t = the number of susceptibles

I_t = the number of individuals infected with HIV

C_t = the number of frank cases of AIDS

Also, define S' as the annual increment to the total population, and d as the annual death rate for AIDS cases.

We employ the basic epidemic assumption that the number of new HIV infections per year is proportional to the number susceptible (S_t) times the proportion of the well population that is currently infected $I_t/(S_t + I_t)$; the constant of proportionality is β_t. Because of heterogeneity in risk behaviors and possible behavior changes, we assume that β_t has been decreasing at a rate of 100b percent per year. Thus,

$$\beta_{t+1} = \beta_t(1-b).$$

We model the natural history of HIV infection as follows. After a guarantee period of g years, a proportion g of people infected with HIV convert to AIDS cases per year. Thus, the number of new AIDS cases in year $t+1$ is $qI_{(t-g)}$. With these definitions, the dynamics of the HIV/AIDS epidemic can be expressed as:

$$S_{t+1} = S_t + S' - \beta_t S_t I_t/(S_t + I_t)$$

$$I_{t+1} = I_t + \beta_t S_t I_t/(S_t + I_t) - qI_{(t-g)}$$

$$C_{t+1} = C_t + qI_{(t-g)} - dC_t,$$

We fit the model to the observed number of diagnosed AIDS cases by finding sets of parameter values which predict the actual number of diagnosed cases between 1981 and 1985. Later data were not used because delays in reporting cases to CDC made them inaccurate. For instance, using a guarantee period g of 9 years, a conversion rate q of 3 percent per year, a death rate d of 50 percent per year, and assuming that the susceptible population S_t was 60 million in 1980 and growing by 0.6 million per year, we found that β_t for 1980 was 0.333 and declining at 34.5 percent per year, and that 1650 people were infected with HIV in 1980. These parameters result in projections that differ from the observed data by no more than five percent in any year.

Interventions

The interventions were modeled as follows. Behavioral prevention that was p percent effective had the effect of lowering β_t every year after 1989 to (100 − p) percent of what it otherwise would have been. A vaccine available in year T had the effect of reducing β_t to zero for all $t \geqslant T$. A treatment available in year T meant that only case-years that would have occurred after year T were not counted against the total.

Tables 6 and 7 give the percentage reduction in the total number infected (for behavioral prevention and vaccine interventions) and total case years (for a treatment intervention).

Table 6. Percentage reduction in total number infected with HIV at a range of effectiveness of behavioral prevention interventions.

Effectiveness of prevention	Percent reduction in number infected
0%	0.0
10	12.5
20	23.8
30	34.2
40	43.5
50	52.0
60	59.5
70	66.3
80	72.4
90	77.8
100	82.5

Table 7. Percentage reduction in total case years of AIDS, given year of availability of vaccine or treatment.

Year available	Reduction in case years of AIDS	
	Vaccine	Treatment
1995	0.0	0.0
1994	25.3	26.2
1993	45.3	46.5
1992	60.9	62.2
1991	73.1	74.3
1990	82.5	83.6

Thus, the following three research results are roughly 'equivalent':

1. Making a vaccine available one year earlier.
2. Making a treatment available one year earlier.
3. Lowering the annual probability that an uninfected susceptible individual becomes infected with the AIDS virus by 20 percent by 1990. (This could be done, for instance, by decreasing the average probability of transmission per act by 20 percent, or by changing the average number of sexual partners of uninfected persons in such a way that his or her probability of becoming infected in a given year is reduced by 20 percent.)

Sensitivity analysis of the model assumption and parameters shows that the *relative* effects of the three interventions are similar under a variety of conditions.

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