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MODELING THE AIDS EPIDEMIC BY ANALYSIS OF SEXUAL AND INTRAVENOUS DRUG BEHAVIOR

PETER W. PLUMLEY

ABSTRACT

This paper presents a model of the progression of the Acquired Immunodeficiency Syndrome (AIDS) epidemic in the United States. The model is developed by projecting the spread of the epidemic within various major categories of the population based on the sexual and intravenous (IV) drug activities that cause transmission of the disease from one person to another.

The model uses assumed frequencies of the various types of sexual and IV drug behavior, combined with probabilities of risk of infection from these acts and rates of progression from infection to AIDS, to develop results for the epidemic from 1981 to 1988. After these results have been validated against AIDS cases actually reported, the epidemic can be projected based on any desired assumptions of future sexual and IV drug behavior. The model projects the epidemic to the year 2030.

Because the model permits easy testing of alternatives based on differing scenarios of sexual and IV drug behavior, it should be helpful in quantifying the impact of public policy decisions on education and testing. It also should be of value to insurance companies, drug companies, health care providers, and any others who want to project mortality or health care demand or costs or who have some other need for a continuing quantitative analysis of the epidemic.

I. INTRODUCTION

This paper presents a model of the progression of the Acquired Immunodeficiency Syndrome (AIDS) epidemic in the United States. The model is developed by projecting the spread of the epidemic within various major categories of the population based on the sexual and IV drug activities (that is, sharing of IV drug needles) that cause transmission of the disease from one person to another.

The model begins with a population in 1981 and an assumed number of persons infected with the human immunodeficiency virus (HIV) at that time. By using assumed frequencies of the various types of sexual and IV drug behavior, combined with probabilities of risk of infection from these acts and rates of progression from infection to AIDS, the number of AIDS cases

and other relevant data can be calculated year by year. Next, the number of modeled AIDS cases for each year through 1988 is compared with known data in order to validate the assumptions. The epidemic can then be projected based on any desired assumptions of future sexual and IV drug behavior.

The model differs from many traditional approaches to epidemic modeling, which have only a limited ability to reflect behavioral changes and which cannot consider the interrelationships between risk groups. Because the model is directly related to sexual and IV drug behavior and because it reflects such interrelationships, it permits easy testing of alternatives based on differing scenarios of such behavior. It should be helpful in quantifying the impact of public policy decisions on education and testing. It also should be of value to insurance companies, drug companies, health care providers, and any others who want to project mortality or health care demand or costs or who have some other need for a continuing quantitative analysis of the epidemic.

The model is able to project the epidemic to the year 2030; however, most of the figures presented in this paper involve projections only to the year 2000. For most purposes longer-term projections are of relatively little value because of the impossibility of making long-term predictions of behavioral trends and because cures, vaccines, or other medical treatments could have a significant impact on the results.

All figures developed by the model exclude HIV infections and AIDS cases arising from blood transfusion recipients, hemophiliacs, and children, which currently amount to about 5 percent of the total cases.

The number of AIDS cases developed by the model are based on date of diagnosis rather than the date that the case was reported to the Centers for Disease Control (CDC). This approach provides a better measure of the progress of the epidemic; however, because many figures published by the CDC and the public press relate only to those cases actually reported to date, the projections presented herein may differ from others reported publicly by the number of diagnosed but not-yet-reported cases.

This paper presents three basic projections of the epidemic, based on low, middle, and high assumptions of future sexual and IV drug behavior. The high projection assumes that the level of sexual and IV drug behavior estimated to exist in 1988 continues into the future without any further modification. The middle projection assumes that current and future AIDS education and prevention efforts will result in further decreases in those sexual and IV drug activities that spread the AIDS virus, particularly those activities that are considered "high-risk." (High-risk activities are anal sex, sharing of IV

drug needles, and heterosexual activity with male bisexuals and IV drug users. The high-risk groups are male homosexuals, male bisexuals, and IV drug users). The low projection assumes that AIDS education and prevention efforts will result in major decreases in those sexual and IV drug activities that spread the AIDS virus.

In addition, other scenarios are tested to isolate the effect of various behavioral changes or to illustrate certain other points.

Although the model has been used only on a national basis in the United States, it could be used to track the spread of the epidemic by state or region. It also could be used to track the epidemic in other countries, provided the necessary data are available.

The remaining sections of this paper are as follows:

- Section II summarizes the key findings of the paper.
- Section III describes the mathematics of the model.
- Section IV discusses the data and assumptions used in modeling the epidemic from 1982 to 1988.
- Section V develops the basic projections and discusses the effect of some possible other scenarios.
- Section VI discusses the data and assumptions used in the projections.
- Section VII concludes the paper.

II. SUMMARY OF KEY FINDINGS

The principal results and key findings on sexual and IV-drug-related AIDS cases in this paper are as follows:

1. The cumulative number of AIDS cases diagnosed through 1991 is projected at about 318,000, with little variation between the low, middle, and high projections.
2. The high projection shows that if there are no further reductions in high-risk sexual and IV drug activity from that assumed in 1988, the cumulative number of AIDS cases will reach 538,000 by 1993 and just under 1.5 million by the year 2000. By then, more than 1.2 million persons will have died from AIDS in the United States.
3. However, even without further reductions in high-risk sexual and IV drug activity, the number of annual new HIV infections has already peaked at about 200,000 in 1986 and will gradually decrease to less than 100,000 per year by the year 2000 as a result of behavioral changes that have already taken place and as the number of persons in high-risk groups (homosexuals, bisexuals, and IV drug users) who are not already infected diminishes because of deaths from AIDS.
4. Substantial further reductions in the number of AIDS cases can be accomplished by further behavioral changes. The middle projection shows that AIDS educational efforts could reduce the number of annual new HIV infections to about one-half of the number shown in the high projection. Under this projection, there would be

nearly 200,000 fewer AIDS cases by the year 2000 than under the high projection. The low projection shows further reductions, including more than 300,000 fewer AIDS cases by the year 2000 than under the high projection.

5. By the year 2000, the middle projection shows that there will have been a total of about 1.3 million AIDS cases, with about 1.1 million deaths. However, by then the annual number of new HIV infections will be only about 20 percent as large as at the peak in 1986, and the number of new AIDS cases will have been diminishing for several years.
6. As of the end of 1988, about 1.2 million persons were infected with the AIDS virus. Based on the middle projection, this number will peak around 1991 and then begin to decline as the annual number of AIDS deaths exceeds the number of new HIV infections.
7. Based on the middle projection, the largest number of AIDS cases will occur in 1995. The largest number of deaths from AIDS will occur in 1997, at which time they will account for about 4 percent of the total deaths in the United States. The number then will begin to diminish as educational and identification programs take effect and as the number of IV drug users decreases because of deaths from AIDS.
8. Based on the middle projection, the number of persons currently with AIDS will continue to rise until 1997, at which time about 210,000 persons will have the disease, and then will begin to decline. Under the high projection, the peak will come in 1999 at about 255,000 persons; under the low projection the peak will come in 1996 at about 190,000.
9. The proportion of AIDS cases coming from the heterosexual population (excluding IV drug users) will increase from the current level of about 5 percent of the total cases to about 16 percent by the year 2000. However, the number of new HIV infections for this group will decrease as they are educated to avoid sexual activity with IV drug users and bisexual men. For heterosexuals, the largest number of AIDS deaths will occur after the year 2000; however, even at its peak the epidemic will account for less than 1 percent of the total deaths from all causes in the heterosexual population.
10. Although the homosexual and IV-drug-using populations will be devastated by the disease, even at its height it will only strike about one-tenth of one percent of the heterosexual population, most of whom will have acquired the disease from sexual activity with IV drug users or bisexual men.
11. Although in past years much of the AIDS epidemic could be traced to homosexuals and bisexuals, since 1986 IV drug users have been the largest single source of the spread of the epidemic. The middle projection shows that this will continue to be the case.
12. Although the risks of homosexual and IV drug activity are serious, the risk of HIV infection from heterosexual activity for those not involved with persons in high-risk groups is extremely low and will remain so.

13. Homosexuals have a significantly greater risk of HIV infection if they have multiple sexual partners. However, multiple sexual partners per se do not cause a significantly greater risk for heterosexuals because of the very low efficiency of heterosexual transmission of the HIV infection.

III. DESCRIPTION OF MODEL

The AIDS Epidemic

During the last several years, AIDS has been the subject of a great deal of attention. Both the experts and the general public have become alarmed at the spread of a disease that has presented many unanswered questions, that is virtually always fatal, and for which at this time there is no known cure or vaccine.

When a person initially becomes infected with the AIDS virus, there are no overt symptoms; however, very soon thereafter antibodies develop in the blood and can be detected by a blood test. These persons are capable of infecting others as soon as they become infected themselves. Most and perhaps all of them will develop and die from AIDS, if no means of interrupting the disease progression is discovered in the meantime. The length of time that the progression takes varies substantially. A few persons develop AIDS within the first couple of years after infection, but most do not develop it until a number of years later.

For the AIDS virus to be transmitted from one person to another, it must get from the infected person into the blood stream of the recipient. There are several ways that transmission of the virus has been documented:

1. By anal intercourse, generally from the insertive partner to the receptive partner. This happens fairly readily because the lining of the anus is easily torn and because it is designed to absorb moisture. It is through this method that homosexual and bisexual males generally have become infected.
2. By vaginal intercourse. The experts generally believe that the AIDS virus can be transmitted from men to women by vaginal intercourse, although the probability of transmission from a single act of sex with an infected person is very low. They also believe that it can be transmitted from women to men in the same manner, though most believe that the risk is even lower.
3. By insertion of a needle or blood product contaminated with the AIDS virus into the blood stream. This is the manner by which IV drug users are transmitting the virus. It also has been the cause of AIDS among hemophiliacs and other persons receiving blood transfusions. In addition, there have been a few instances of transmission in which medical personnel accidentally have been stuck with contaminated needles or other sharp instruments.

4. By transmission from mother to child before birth, because they share a common blood system during that period.

There also have been some alleged cases of transmission from "freak" situations, such as a bite, kissing, and casual contact of one type or another. Although these occasionally are reported in the press, they generally are unproven, very rare, and not of significance in modeling the epidemic.

This paper is concerned only with the transmission of the AIDS virus by sexual and IV drug activity. According to data published by the CDC, these modes of transmission account for more than 95 percent of AIDS cases to date and probably will account for an even higher percentage now that blood is screened for the AIDS virus before being used in blood transfusions. All figures developed by the model and presented in this paper exclude those AIDS cases arising from other than sexual or IV drug activity.

Basic Modeling Approach

The basic concept of the model described in this paper is that, because AIDS is transmitted primarily by certain definite activities, it is possible to develop a predictive model in terms of those activities. The model operates in three major phases; these phases develop: (1) the number of HIV+ persons, (2) the number of persons developing AIDS, and (3) the number of deaths from AIDS.

To develop the number of HIV+ persons, the population is divided by risk group, and the number of new infections is calculated based on behavior and probability of infection.

The persons infected in a calendar year form a cohort in the infected group. The number of persons developing AIDS is then calculated by applying the appropriate probability based on time since infection. The total number of new AIDS cases in a year is the sum of the new cases from each cohort.

A similar technique is used to calculate the number of AIDS deaths. The AIDS cases are maintained by cohort. Mortality rates are applied based on time since the onset of AIDS. The total number of deaths is the sum of the deaths from each cohort.

Specifically, new AIDS cases can be predicted if the following are known:

1. The number of HIV+ persons
2. The number of sexual or drug contacts by these infected persons with persons not already infected
3. The probability that the infection will be transmitted through a single sexual or IV drug contact

4. The rates of progression from HIV+ to AIDS.

A problem for all AIDS models is the lack of reliable data. For example:

1. The current number of HIV infections can only be estimated. In general, this has been done by projecting data developed from various population samples. Unfortunately, these samples generally are subject to some bias, so that reliable estimates for the population as a whole currently are not possible by this method.
2. The frequency of sexual activity with infected persons is not accurately known (and of course varies considerably).
3. Although some studies have indicated the efficiency with which the virus transmits during vaginal intercourse, there is less reliable data on anal intercourse and IV drug use.
4. Although there are studies tracing the progress from HIV+ to AIDS during the first few years after infection, long-term progression estimates currently are of necessity based on extrapolation of the data for early durations.
5. Although the number of AIDS cases is known with a fairly good degree of accuracy in total (though with some undercounting), the determination of risk factors depends on the reliability of answers given by the AIDS victims. Unfortunately, many of these victims may have reason to hide the risk factors applicable to them.

The reliability of data is discussed further in Section VI.

The basic approach used in the model is to assume that certain data that are known with at least some degree of accuracy are correct and then to use a trial-and-error process to determine other historical data. This is done by projecting the number of AIDS cases and deaths through 1988 and then comparing the results with actual data provided by the CDC. Once this validation process is completed, the number of AIDS cases and deaths and HIV infections can be projected to the year 2030, based on any desired assumptions of sexual and IV drug behavior. By varying the assumed sexual and IV drug behavior for future years, it is possible to show the effect of these changes on the progression of the disease.

The following data were assumed to be correct:

1. Total population figures for 1982 for ages 16 and over were taken from data published by the Bureau of Census.
2. It was assumed that this population included certain percentages of homosexuals, bisexuals, and IV drug users. These percentages were based on various reported studies and estimates.
3. Rates of progression from HIV+ to AIDS were assumed based on a longitudinal study of San Francisco blood samples.
4. Rates of progression from AIDS to death were assumed, based on CDC data.
5. A probability of infection for engaging in each of the various sexual and drug acts with an infected partner was assumed. For vaginal intercourse, this probability was

based on published data. For anal intercourse and IV drug use, the probability was estimated.

In a later section of the paper, these assumptions are discussed in more detail, and the effects of variations in some of them are shown.

The approach is to assume that the figures developed above are accurate and then make a guess at two sets of figures:

1. The "average" annual frequency of the various sexual and drug activities. (The use of the quotation marks around "average" is discussed later in the paper.)
2. The number of HIV infections in 1981 for each category and their distribution by year of infection.

Because of the substantial differences in the incidence of AIDS by race, all results were subdivided by race (black, white, and other). Also, all results were subdivided by homosexual, bisexual, IV drug user, and heterosexual. (Note: the term heterosexual, as used in this paper, excludes IV drug users.)

By using the initial guesses of the above figures, coupled with the estimates of the other data discussed above, the number of AIDS cases and deaths by category can be projected from 1982 through 1988, using the formulas to be discussed later. Because the actual number of such cases and deaths is reported by the CDC, the projection then can be compared with the actual data modified to allow for diagnosed and unreported cases. By a trial-and-error process, assumptions can be developed on the number of 1981 infections and the frequency of sexual and drug acts that closely reproduce the known data on AIDS cases.

The model was designed to be used on a national basis, without distinguishing by geographic region. However, to the extent that data are available on a more localized basis, such as by state or a group of states, the model could be used to project the epidemic for any such locality.

Details of the Modeling Approach

The AIDS risk varies according to the nature of one's sexual partners. For married couples who have been and will continue to be monogamous, AIDS presents absolutely no possible risk with regard to sexual behavior, unless one of the marriage partners has become infected through some unfortunate circumstance such as a blood transfusion with infected blood. On the other extreme, promiscuous people whose sexual partners extend into the drug community have significant risk of exposure.

The AIDS risk also varies geographically. New York and California are known to have the highest number of AIDS cases relative to the population, while some rural states have very few cases.

A model that accurately depicts the spread of the epidemic for a wide variety of subgroups of the population was not considered practical. To do so would have considerably complicated the model and would have required data that are to a large extent unknown. Instead, the approach was to assume that, within each racial group, the various types of sexual and IV drug activity are not segregated by geography, social class, or other strata such as degree of promiscuity.

Certain other simplifying assumptions also had to be made, either to avoid overcomplicating the model or because of a lack of valid data, or both. These simplifications do not have a material effect on the modeling approach or on the resulting projections. These assumptions are as follows:

1. No interracial sexual activity or sharing of IV drug needles takes place.
2. Homosexual men engage in sexual activity only with other homosexual and bisexual men.
3. Bisexual men engage in sexual activity with other bisexual men, with homosexual men, and with heterosexual women; however, their risk of infection comes only from other men, thus ignoring the much smaller risk of becoming infected from engaging in vaginal sex with an infected woman.
4. IV drug users risk infection only from engaging in needle-sharing with other IV drug users, thus ignoring the much smaller risk of becoming infected from vaginal sex.
5. Those homosexual or bisexual men who were also IV drug users were split between those two categories, so that the IV drug users have a risk only from IV drugs, and the homosexual and bisexual men have a risk only from receptive anal intercourse. This assumption ignores the possible increased susceptibility to the AIDS virus because of the combination of anal intercourse and IV drug use.
6. For years prior to 1987, persons with AIDS were just as likely to engage in sexual or needle-sharing activities as were those who were HIV + but who had not actually contracted AIDS. However, beginning in 1987, public education progressed to the point that persons who actually had AIDS no longer had any sexual or needle-sharing activity unless their sexual or IV drug partner was fully protected from acquiring the disease.
7. For years prior to 1987, heterosexual men engaged in sexual activity at random with heterosexual women, both IV drug users and others. However, for years beginning with 1987, a "discrimination factor" was added to the formula, so that the model could measure the effect of various degrees of avoidance of sexual activity with female IV drug users.
8. For years prior to 1987, heterosexual women engaged in sexual activity at random with heterosexual and bisexual men, including IV drug users. However, for years beginning in 1987, two "discrimination factors" were added to the formula. One of these permitted the model to measure the effect of various degrees of avoidance of sexual activity with male IV drug users, and the other allowed the model to

measure the effect of various degrees of avoidance of sexual activity with bisexual men.

9. For years prior to 1987, persons generally did not have knowledge of their HIV status, and therefore, in choosing a sexual or IV drug partner, one would not be able to exclude anyone because he or she was infected. However, for years beginning in 1987, a "knowledge factor" was added to the formulas for all categories, to permit the model to reflect the availability of information on HIV status.

Description of Formulas

As previously discussed, one of the simplifying assumptions in the model is that the three major population groups of white, black, and other are not involved in any drug or sexual activities with each other. An initial population of N_m males and N_f females over the age of 16 was assumed to exist in 1982, based on census data. This population was then split between white, black and other. The figures used are shown later in the paper.

The next step was to calculate the number of homosexuals, bisexuals, and IV drug users for each racial group. This was done by applying percentages to the total population. These percentages varied by racial group. A detailed description of the calculation of these percentages is given later in the paper. Those who did not fall into one of the above categories were classified as heterosexuals.

For 1982, the number of persons in each category was determined by multiplying the total population (split by race) by the various percentages described above.

For 1983 and 1984, the number of persons in each category was determined by multiplying the figures for the prior year by 1.0135, which was estimated to be the annual population growth based on recent census data. It was not thought necessary to refine the population figures to reflect any variations by age, race or sex.

For years after 1984, however, an additional refinement was added. The projection goes to the year 2030, but long before then, the high-risk groups will have been greatly impacted by AIDS. Because of this, for years after 1984 a downward adjustment should be made to reflect the number of AIDS deaths in each category. Therefore, beginning in 1985 the number of persons in each category was calculated to be the arithmetic sum of the following:

(1) The population in the category for the previous year, plus
(2) The increase in population in the category from 1983 to 1984, less
(3) The deaths from AIDS in the category in the previous year.

The number of persons becoming infected each year was determined by using formulas that varied according to the particular category. For homosexuals, the formula for each racial category was:

$$VH_n = (NH_n - IH_{n-1}) \times \left\{1 - \left[1 - \frac{p_a \times {}_hK_n \times (IH_{n-1} + IB_{n-1} - AH_{n-1} - AB_{n-1})}{NH_n + NB_n - (1 - {}_hK_n)(IH_{n-1} + IB_{n-1} - AH_{n-1} - AB_{n-1})}\right]^H\right\}$$

where

VH_n = the number of new infections from homosexual activity for that racial category in year n.

NH_n = the number of homosexuals in that racial category in year n.

IH_{n-1} = the number of homosexuals in that racial category already infected by year $n-1$.

NB_n = the number of male bisexuals in that racial category in year n.

IB_{n-1} = the number of male bisexuals in that racial category already infected by year $n-1$.

p_a = the probability of infection from a single act of unprotected receptive anal intercourse.

${}_hK_n$ = the "knowledge factor" in year n for homosexuals to reflect knowledge of which homosexuals were HIV+. A knowledge factor of 1 means that there is no knowledge about who is HIV+. A knowledge factor of 0 means that everyone who is HIV+ knows that he is and accordingly refrains from sexual activity with uninfected partners. This factor applies only to 1987 and later years.

AH_{n-1} = the number of homosexuals in that racial category with AIDS in year $n-1$. This factor applies only to 1987 and later years.

AB_{n-1} = the number of bisexuals in that racial category with AIDS in year $n-1$. This factor applies only to 1987 and later years.

H = the average number of acts of unprotected receptive anal intercourse engaged in during the year by the homosexuals in that category.

For male bisexuals, a formula similar to that for homosexuals was used, namely:

$$VB_n = (NB_n - IB_{n-1}) \times \left\{1 - \left[1 - \frac{p_a \times {}_bK_n \times (IH_{n-1} + IB_{n-1} - AH_{n-1} - AB_{n-1})}{NH_n + NB_n - (1 - {}_bK_n)(IH_{n-1} + IB_{n-1} - AH_{n-1} - AB_{n-1})}\right]^B\right\}$$

where

VB_n = the number of new infections from bisexual activity for that racial category in year n.

${}_bK_n$ = the knowledge factor for bisexuals, similar to that for homosexuals described earlier, and applicable only to 1987 and later years.

IH_{n-1} = the number of homosexuals in that racial category already infected by year $n-1$.

B = the average number of acts of unprotected receptive anal intercourse engaged in during the year by the male bisexuals in that category.

The remaining symbols are as previously defined, and AH_{n-1} and AB_{n-1} apply only to 1987 and later years.

For male IV drug users, the formula used was:

$$VDM_n = (NDM_n - IDM_{n-1}) \times \left\{1 - \left[1 - \frac{p_a \times {}_dK_n \times (ID_{n-1} - AD_{n-1})}{ND_n - (1 - {}_dK_n)(ID_{n-1} - AD_{n-1})}\right]^D\right\}$$

where

VDM_n = the number of new infections for males in that racial category from IV drug activity in year n.

NDM_n = the number of male IV drug users in that racial category in year n.

IDM_{n-1} = the number of male IV drug users in that racial category already infected by year $n-1$.

${}_dK_n$ = the "knowledge factor" for IV drug users. similar to that described for homosexuals earlier. This term applies only to 1987 and later years.

AD_{n-1} = the number of IV drug users of both sexes already with AIDS in year n. This term applies only to 1987 and later years.

ND_n = the number of IV drug users of both sexes in that racial category in year n.

ID_{n-1} = the number of IV drug users of both sexes in that racial category already infected by year $n-1$.

p_d = the probability of infection from a single act of unprotected IV drug activity (that is, needle-sharing).

D = the average number of acts of unprotected IV drug activity engaged in during the year by IV drug users in that category.

The remaining symbols are as previously defined, and AD_{n-1} applies only to 1987 and later years.

For female IV drug users, the formula used was the female equivalent of the formula for male IV drug users, namely:

$$VDF_n = (NDF_n - IDF_{n-1}) \times \left\{1 - \left[1 - \frac{p_a \times {}_dK_n \times (ID_{n-1} - AD_{n-1})}{ND_n - (1 - {}_dK_n)(ID_{n-1} - AD_{n-1})}\right]^D\right\}$$

where

VDF_n = the number of new infections for females in that racial category from IV drug activity in year n.

NDF_n = the number of female IV drug users in that racial category in year n.

IDF_{n-1} = the number of female IV drug users in that racial category already infected by year $n-1$.

The remaining symbols are as previously defined, and ${}_bK_n$ and AD_{n-1} apply only to 1987 and later years.

For male heterosexuals, the formula used was more complex, because it was assumed that when the male heterosexual engaged in sexual activity, his female partner might be an IV drug user. The formula was:

$$VM_n = (NM_n - IM_{n-1}) \times \left[1 - \left(1 - \frac{p_p \times {}_fK_n \times [{}_dD_n(IDF_{n-1} - ADF_{n-1}) + IF_{n-1} - AF_{n-1}]}{\left\{\begin{array}{l} {}_dD_n \times NDF_n + NF_n - (1 - {}_fK_n) \\ \times\ [{}_dD_n\,(IDF_{n-1} - ADF_{n-1}) + IF_{n-1} - AF_{n-1}] \end{array}\right\}}\right)^V\right]$$

where

VM_n = the number of new infections for male heterosexuals in that racial category from penile-vaginal sexual activity in year n.

NM_n = the number of male drug-free heterosexuals in that racial category in year n.

${}_dD_n$ = the "discrimination factor" in year n for sexual activity with IV drug users. For example, a factor of 0.8 would indicate

that the average male heterosexual would be only 8/10ths as likely to have vaginal intercourse with an IV drug user as would otherwise be the case. This factor applies only to 1987 and later years.

$_fK_n$ = the "knowledge factor" for female heterosexuals. This factor reflects the knowledge that female heterosexuals have of their HIV status. A factor of 1 indicates no knowledge; a factor of 0 indicates that all female heterosexuals who are HIV+ and who might otherwise engage in heterosexual activity are aware of their status and therefore refrain from all such activity. This factor applies only to 1987 and later years.

IF_{n-1} = the number of female drug-free heterosexuals in that racial category already infected by year $n-1$.

ADF_{n-1} = the number of female IV drug users already with AIDS. This factor applies only to 1987 and later years.

AF_{n-1} = the number of female drug-free heterosexuals already with AIDS. This factor applies only to 1987 and later years.

NDF_n = the number of female IV drug users in that racial category in year n.

NF_n = the number of female drug-free heterosexuals in year n.

p_P = the probability of infection for a male from a single act of unprotected penile-vaginal sexual activity.

V = the average number of acts of unprotected penile-vaginal sexual activity engaged in during the year by male heterosexuals in that racial category.

The remaining symbols are as previously defined.

For female heterosexuals, the formula becomes even more complex, for two reasons. First, it is necessary to allow for sexual contact between female heterosexuals and bisexual males, as well as IV drug users. Second, it is necessary to allow for receptive anal sex engaged in by females. The formula thus becomes:

$$VF_n = (NF_n - IF_{n-1})\left\{1 - \left[1 - p_v \times {}_mK_n \times \left(\frac{{}_bD_n(IB_{n-1} - AB_{n-1}) + {}_dD_n(\mathrm{IDM}_{n-1} - ADM_{n-1}) + IM_{n-1} - AM_{n-1}}{\left\{({}_bD_n \times NB_n) + ({}_dD_n \times ND_n) - (1 - {}_mK_n)[{}_bD_n(\mathrm{IB}_{n-1} - AB_{n-1}) + {}_dD_n(IDM_{n-1} - ADM_{n-1}) + IM_{n-1} - AM_{n-1}]\right\}}\right)\right]^V$$

$$\times \left[1 - p_a \times {}_mK_n \right.$$

$$\left. \times \left(\frac{{}_bD_n(IB_{n-1} - AB_{n-1}) + {}_dD_n(IDM_{n-1} - ADM_{n-1}) + IM_{n-1} - AM_{n-1}}{\left\{ ({}_bD_n \times \mathrm{NB}_n) + ({}_dD_n \times ND_n) - (1 - {}_mK_n)[{}_bD_n(IB_{n-1} - AB_{n-1}) + {}_dD_n(IDM_{n-1} - ADM_{n-1}) + IM_{n-1} - AM_{n-1}] \right\}} \right)^A \right]$$

where

VF_n = the number of new infections for female drug-free heterosexuals in that racial category from vaginal or anal sexual activity in year n.

NF_n = the number of female heterosexuals in that racial category in year n.

IF_{n-1} = the number of female heterosexuals in that racial category already infected by year $n-1$.

p_v = the probability of infection for a female from a single act of unprotected vaginal sexual activity.

${}_bD_n$ = the "discrimination factor" for bisexual males, similar to that for IV drug users described earlier. This factor applies only to 1987 and later years.

${}_mK_n$ = the "knowledge factor" for heterosexual males, similar to that described earlier for heterosexual females. This factor applies only to 1987 and later years.

ADM_{n-1} = the number of male IV drug users with AIDS in year $n-1$. This factor applies only to 1987 and later years.

AM_{n-1} = the number of male drug-free heterosexuals with AIDS in year $n-1$. This factor applies only to 1987 and later years.

V = the average number of acts of unprotected vaginal sexual activity engaged in during the year by female heterosexuals in that racial category.

A = the average number of acts of unprotected anal sexual activity engaged in during the year by female heterosexuals in that racial category.

The remaining symbols are as previously defined, and ${}_bD_n$ applies only to 1987 and later years.

Once the number of new HIV infections was calculated, the number of new AIDS cases for each category was determined for each year by applying the rates of progression from HIV infection to AIDS, calculated as described later in this paper. The general formula for each category was as follows:

$$A_n = (V_{n-1} \times P_1) + (V_{n-2} \times P_2) + (V_{n-3} \times P_3) + \ldots$$

where

A_n	=	the number of new AIDS cases for that category in year n.
V_{n-1}, V_{n-2}, etc.	=	the number of new HIV infections for that category in year $n-1$, $n-2$, etc.
P_1, P_2, etc.	=	the percentage of infected persons who will develop AIDS in 1, 2, etc. years after infection.

No specific allowance was made for deaths from other causes between the time of HIV infection and the development of AIDS. To make such an allowance would have complicated the model in a manner not thought necessary in view of the relatively few years involved, on the average, between infection and the onset of AIDS, and the low average age of AIDS victims. However, the progression rates used in the paper extend only for 20 years and assume that only 93 percent of HIV+ persons eventually develop AIDS; this could be said to allow for mortality from other causes.

The number of deaths from AIDS was calculated in a manner similar to that for progression from HIV+ to AIDS, by applying the progression rates from AIDS to death (shown later in the paper) to the number of new AIDS cases each year in each category.

IV. DATA AND ASSUMPTIONS USED IN THE MODEL

The model is based on known data and an analysis of the process of becoming infected, converting from HIV+ to AIDS, and then dying from AIDS. As already discussed, a trial-and-error process is used to supplement known data and to fit assumptions of sexual and IV drug behavior into known data on AIDS cases and deaths as well as into partially known data on transmission efficiency. This section discusses the basic data and assumptions used in the model and in the validation process. Section VI contains further discussion and analysis of the behavioral and other assumptions used in projecting the epidemic to the years ahead.

The Data Bank Compiled by the Centers for Disease Control

The CDC is the basic source for data on the AIDS epidemic used in the development of the projections. AIDS cases are reported to the CDC by the national system for collection of information on certain diseases from state and local health departments. Because of the interest in the AIDS epidemic,

the CDC makes available to the public a data base on AIDS cases and deaths that have been reported to them. This data base contains one record for each AIDS case. It is available on a computer diskette and is updated each quarter. This paper uses data reported to the CDC through September 30, 1988. The following information is available for each AIDS case and was used in some way in this paper:

- Age group
- Sex class (homosexual male, bisexual male, heterosexual male, and heterosexual female)
- Race (white, black, hispanic, and other)
- Year and month during which the first AIDS-associated opportunistic disease was diagnosed
- Year and month in which the AIDS case report was received by the CDC
- Death code (indicating whether the person has died)
- Year and quarter of death, for those persons who have been reported to have died
- Hierarchical patient group (for nonpediatric cases, the classifications are: (1) homosexual or bisexual, (2) IV drug user, (3) homosexual or bisexual who also uses IV drugs, (4) hemophiliac, (5) heterosexual contact of a person at risk for AIDS, contact of a person with AIDS, or contact of a person with a positive HIV test, (6) born outside the U.S., (7) transfusion recipient, and (8) other/undetermined).

In addition, the data base includes several other codes, such as region of residence and cause of death, which were not used in the paper.

Classification of Persons Who Are Diagnosed As Having AIDS

A key item of information in the development of the projections is the hierarchical patient group classification referred to above. Patients with multiple risk factors are shown in the group listed first. Thus, for example, a homosexual who also was reported to have had a blood transfusion that might have caused him to become infected would nevertheless be shown as being in category 1.

The CDC obtains its information from the various information-collecting sources around the country. The CDC classifies AIDS cases based on the information provided by its sources. For a case to be classified as "heterosexual transmission," a heterosexual partner must be named. Nevertheless, the CDC faces a significant problem of the reliability of these classifications, because of the stigma attached to having AIDS. Attempts have been made to persuade the public that anyone can get the disease; nevertheless, most AIDS victims are either homosexual, bisexual, or IV drug users. And the first reaction that many people have to information that someone has AIDS

is that the person is in one of those high-risk categories. In light of the desire and opportunity for persons to conceal information about their high-risk activities, some who acquired AIDS through homosexual or IV drug means might be expected to claim that they had instead become infected by heterosexual contact.

On the other hand, a heterosexual who admitted to being an IV drug user, and therefore would be classified as such in the hierarchical ranking, might have in fact acquired the infection from heterosexual contact, even though such would appear to be much less likely.

The projections in this paper have taken the CDC classifications at their face value and have not attempted to make any adjustments for any bias due either to deliberate misstatements by AIDS patients or to the effects of the hierarchical rankings.

Undercounting of AIDS Cases

For reasons of stigma as well as certain technical problems, some AIDS cases are not being reported to the CDC, and some AIDS deaths are being reported as from other causes. Although estimates of as high as 50 percent have been made, there does not seem to be any reliable information on the degree of such undercounting. The CDC estimates that it ultimately learns of 84 percent of AIDS cases.

It is believed that the percentage of undercounting was most serious in the first few years of the epidemic, when many doctors may not have recognized the symptoms of the disease. Also, in 1987 the definition of AIDS was revised. This change also appears to have reduced the amount of undercounting.

In carrying out the validation process, some allowance was made for the early undercounting of cases. Otherwise, the projections in this paper have not taken into account any undercounting, because there does not seem to be any way to make a reasonable estimate of its extent. The effect of undercounting on the projections is analyzed in Section VI.

Rate of Conversion from HIV+ to AIDS

The model calculates the number of new HIV infections from the number of unprotected sexual or drug acts and the probability of infection from a given act by using the formulas described earlier. Once the number of new infections is determined for each year, the progression from HIV+ to AIDS

can be calculated if the rates of progression are known. Part 2 of the Cowell-Hoskins paper [5] developed a scale of progression rates extending for 25 years from date of HIV infection (see Table 9 of that paper). This scale was based on a study of a group of 543 subjects from groups at high risk at the University of Frankfurt from 1982 through 1985 (the Frankfurt Study HIV Progression Rates, or Frankfurt rates) [2]. Subsequently, in an addendum to their paper Cowell and Hoskins presented comparable figures based on data from frozen blood samples taken annually and dating back to 1978 for 719 San Francisco male homosexuals and bisexuals (the San Francisco City Clinic/CDC HIV Progression Rates, or SFCC/CDC rates) [9]. Table 1 compares these two scales of progression rates.

TABLE 1

COMPARISON OF PROGRESSION RATES FROM FRANKFURT STUDY AND SAN FRANCISCO CITY CLINIC STUDY

Number of Years Since HIV Infection	Percentage of Persons Who Have Progressed to AIDS or Death			
	Current Year		Cumulative	
	SFCC/CDC	Frankfurt	SFCC/CDC	Frankfurt
1	0.3%	0.2%	0.3%	0.2%
2	1.2	2.5	2.5	2.7
3	2.6	9.7	5.1	12.4
4	4.3	11.3	9.4	23.7
5	6.2	9.7	15.6	33.4
6	8.6	8.2	24.2	41.6
7	10.4	7.3	34.6	48.9
8	10.0	6.6	44.6	55.5
9	8.4	5.9	53.0	61.4
10	7.2	5.2	60.2	66.6
11	6.1	4.6	66.3	71.2
12	5.2	4.1	71.5	75.3
13	4.5	3.5	76.0	78.8
14	3.7	3.1	79.7	81.9
15	3.2	2.7	82.9	84.6
16	2.7	2.3	85.6	86.9
17	2.3	1.9	87.9	88.8
18	2.0	1.7	89.9	90.5
19	1.7	1.5	91.6	92.0
20	1.4	1.2	93.0	93.2

Because the validation process works backward from the actual numbers of AIDS cases, a slower scale of progression rates will result in a larger number of HIV infections and, ultimately, a larger number of AIDS cases. Therefore the scale of progression rates is very important in measuring the

scope of the epidemic. The projections in this paper are based on the SFCC/CDC rates except where otherwise indicated. The SFCC/CDC rates appear to be more representative of the AIDS epidemic in the U.S. than the Frankfurt rates and result in a current level of HIV infections more consistent with other estimates. As Table 1 indicates, they are the slower of the two scales and therefore give a larger number of HIV infections. A comparison of projections using both scales is shown in Section VI.

Rate of Progression from AIDS to Death

Rates of progression from AIDS to death were also needed. To develop this scale, section G of the CDC *AIDS Weekly Surveillance Report* of July 20, 1987 [3] was used. This section shows cumulative AIDS cases by half-year of diagnosis, beginning with January 1981. Annual fatality rates were calculated by combining case fatality rates for pairs of six-month periods. Actual CDC rates were used for the first five years after diagnosis, at which point it was assumed that 87 percent of AIDS victims have died. After five years, annual rates were arbitrarily graded in order to total 100 percent after ten years, at which point it was assumed that everyone has died. Table 2 shows the resulting scale of rates of progression from AIDS to death.

TABLE 2

Number of Years Since Developing AIDS	Percentage of Persons Dying	
	Current Year	Cumulative
0	30%	30%
1	30	60
2	15	75
3	7	82
4	5	87
5	4	91
6	3	94
7	3	97
8	2	99
9	1	100

Probability of Infection for a Female from a Single Act of Vaginal Sex with an Infected Partner

As mentioned earlier, the model develops the number of HIV infections and resulting number of AIDS cases by using a formula that takes into

account the number of unprotected acts of sex or IV drug use and the risk of infection from a single act. Unfortunately, data on these factors are not known with a high degree of certainty; however, some information is available with respect to the risk from a single act of sex with an infected partner. A study reported in the *Journal of the American Medical Association* [8] of the female sex partners of men infected with HIV found that 23 percent of the 97 women studied were infected. Sixty-five of these women reported more than 100 sexual contacts with the men. Twenty-nine reported having anal intercourse with the men.

By using standard probability formulas, a table can be developed showing the proportion of persons who will become infected given (1) the number of sexual encounters with an infected person and (2) the probability of infection from a single encounter. Table 3 shows a scale of such probabilities.

TABLE 3

PROBABILITY OF TRANSMISSION OF HIV INFECTION BY SEXUAL ACTIVITY WITH AN INFECTED PARTNER

Number of Sexual Acts	Probability of Infection from a Single Sexual Act					
	0.0005	0.001	0.00125	0.002	0.005	0.01
	Percentage of Persons Infected					
10	0%	1%	1%	2%	5%	10%
20	1	2	2	2	10	18
30	1	3	4	6	14	26
40	2	4	5	8	18	33
50	2	5	6	10	22	39
60	3	6	7	11	26	45
70	3	7	8	13	30	51
80	4	8	10	15	33	55
90	4	9	11	16	26	60
100	5	10	12	18	39	63
110	5	10	13	20	42	67
120	6	11	14	21	45	70
130	6	12	15	23	48	73
140	7	13	16	24	50	76
150	7	14	17	26	53	78
160	8	15	18	27	55	80
170	8	16	19	29	57	82
180	9	16	20	30	59	84
190	9	17	21	32	61	85
200	10	18	22	33	63	87

The *JAMA* study shows that 23 percent of the sexual partners became infected. However, this probably overstates the true percentage infected by vaginal intercourse, for two reasons:

1. Five of the 22 persons infected were sex partners of IV drug users. This study and others indicate that sex partners of IV drug users have a higher rate of infection than those of other infected persons. This suggests that some of the women may in fact have become infected from sharing needles with their lovers or from some other type of accident or incident involving a contaminated needle, rather than from vaginal sexual activity. (Alternatively, it could suggest that sexual activity with an IV drug user tends to be more violent and thus more likely to tear the vaginal wall and transmit the virus, if he is infected.)
2. Eleven of the 22 infected women admitted to having engaged in receptive anal intercourse. Anal intercourse is considered to be a more risky type of sexual activity than vaginal intercourse and is the reason that homosexual men have been so heavily victimized by AIDS. It seems reasonable to assume that at least some of those engaging in anal intercourse became infected from that method rather than from vaginal intercourse.

We can only guess how many of the 22 infected persons actually became infected through IV drug use or anal intercourse. However, it seems reasonable to assume that about half of the five infected partners of the IV drug users were infected from needles rather than from sexual activity. It also seems reasonable to assume that about half of the infected persons who practiced anal sex became infected in that manner. Combining these two adjustments, we can reduce the number of infections from vaginal intercourse from 22 to 14.

Next, we must make some assumptions on how many acts of sex these infected women engaged in. The study indicates that 65 of the women in the study engaged in more than 100 acts each and that 20 of these women became infected. After making the adjustment mentioned above, we can estimate that about 12 out of these 65, or 18 percent, became infected through vaginal sex. Also, 2 out of the remaining 32, or 6 percent, who engaged in less than 100 sexual acts became infected.

As shown in Table 3, if the 65 women averaged 160 sexual acts each and the 32 women averaged 50 acts each, the probability of infection from a single act of sex with an infected male partner would work out to be 0.00125, or 1 in 800. Obviously, different assumptions on the number of acts and the number of persons who actually became infected from other means can vary this figure somewhat, but it probably is approximately correct and is consistent with other studies. For example, Hearst and Hulley [6] state that

"The available data suggest that the infectivity of male-to-female vaginal intercourse is 0.002 or less."

Probability of Infection for a Male from a Single Act of Vaginal Sex with an Infected Partner

The probability of infection for females of 1 in 800 can be verified to some degree by published data and appears to be consistent with the epidemiology on the subject. However, the risk is less clear for female-to-male transmission. In the absence of good data to the contrary, the model assumes that the risk of transmission from female to male is the same as that of male-to-female, that is, 1 in 800, per act with an infected partner. However, many authorities believe that the efficiency of female-to-male transmission is less than that of male-to-female transmission.

Variation in Probability of Infection from Vaginal Sex

The risk factors described above for the transmission of the virus through a single act of vaginal sex with an infected partner are statistical averages. However, there are reasons to believe that the probability varies considerably according to several cofactors, including:

1. History of other sexual disease. A number of studies have shown a correlation between AIDS and other sexually transmitted diseases such as syphilis and gonorrhea. Two reasons are suggested for this: First, these diseases may leave sores in the genital area that permit access to the blood stream. Second, the drugs used to combat these diseases may damage the body's immune system and thereby permit access to the body by the AIDS virus more easily than would otherwise be the case.
2. Length of time since infection. A number of medical researchers believe that the degree of infectivity varies considerably according to the length of time since the person became infected and the state of his or her health. The belief is that very soon after a person becomes infected, his degree of infectivity is high. Then the AIDS antibodies begin to build up in the body. At that point, the standard AIDS antibody test will show that the person is HIV + for the first time. Also at that point, the degree of infectivity drops to a low level. Later, as the person begins to show the symptoms of AIDS, the infection begins its process of destroying the immune system and also reduces the level of antibodies. At that point, the level of infectivity goes higher.
3. Number of previous exposures to the virus. Some have speculated that under normal circumstances it takes repeated exposure to the virus to become infected, particularly through vaginal sex. Many of the heterosexuals who have become infected have been the regular sexual partners of infected persons. The question here is whether

this is because repeated doses of the virus are needed for transmission or whether this has occurred simply because the regular sex partners have more sexual contacts with infected persons and are more easily identified as such.

4. Degree of inherent susceptibility to the virus. Are there some people who, apart from the factors just discussed, are inherently more susceptible than others to the virus? At present, there doesn't appear to be any real evidence to this effect, but if such were in fact the case, it would be very helpful in identifying risk levels.

The model is unable to directly reflect these variations in the degree of susceptibility to infection; however, it can do so indirectly by varying the "average" number of heterosexual contacts per year.

Probability of Infection from a Single Act of Receptive Anal Sex with an Infected Partner

The AIDS virus has spread rapidly among homosexual males. It is well established that anal sex is the principal means of transmission within this group. This rapid spread has occurred for three reasons:

1. The risk per act of receptive anal intercourse appears to be significantly higher than that for vaginal intercourse.
2. Many homosexual men are very promiscuous and engage in a larger number of sexual acts with more partners than would be expected from the average heterosexual.
3. It is estimated that by 1988 more than 17 percent of the homosexual population was infected, thereby giving a significant risk that one's homosexual partner is infected.

Although the risk of receptive anal intercourse with an infected partner appears to be greater than for vaginal sex, there are few reliable data. The model assumes a probability of infection per act with an infected partner of 0.01, or 1 percent. This is discussed further in Section VI.

Probability of Infection from Needle-Sharing with an Infected Person

It also is necessary to estimate the probability of infection from sharing an IV drug needle with an infected person. The author is unaware of any study that has been made to determine this risk; however, it would seem to be considerable. The arbitrary assumption has been made that the risk is 1.5 percent per act.

Number and Distribution of AIDS Cases Diagnosed to Date

The most important data used to validate the model are the number and distribution of AIDS cases that have actually been diagnosed in each calendar

year through 1988. In order to get these figures in a usable form, the following steps must be taken:

1. Since there is a lag between the time an AIDS case is diagnosed and the time it is reported to the CDC, information must be developed on the "aging factors" that should be used to allow for cases diagnosed but not yet reported.
2. Next, the number of AIDS cases for each of the various sex, race, and risk groups that have been reported in each calendar year must be tabulated and then increased by the "aging factors," in order to determine the number of cases in each category that are estimated to have been diagnosed in each year.
3. Finally, certain of the data must be combined or reallocated. This is necessary because (a) the model combines hispanics and all other races except white and black into one category, (b) those cases classified by the CDC as "homosexual and IV drug user" must be allocated to either homosexual or IV drug user, because the model does not allow for a combined category, and (c) the "born outside the U.S." and "undetermined" categories must be allocated to one or more of the risk groups used by the model.

Development of "Aging Factors"

The first step in the development of the "aging factors" was to sort the AIDS cases diagnosed in 1984 by quarter of reporting. The year 1984 was used because it was far enough in the past so that most of the cases diagnosed in that year would have been reported by the end of the third quarter of 1988, while at the same time it was recent enough so that the number of cases was large enough to give valid results. Because it appeared that some additional cases still were to be reported with date of diagnosis even as far back as 1984, arbitrary numbers were added to the figures to allow for such cases. The resulting figures are shown in Table 4.

Next, similar data were developed for other years. Examination of these data indicated that some downward adjustments should be made in the percentages shown in the last column of Table 4. Table 5 shows a comparison of the aging factors developed from 1984 data with those finally used in calculating the number of AIDS cases by date of diagnosis.

Calculation of Number of AIDS Cases Diagnosed in Each Year

The development of the number of AIDS cases diagnosed each year for each category was done by applying the aging factors shown in the last column of Table 5 to the number of cases reported by the end of the third quarter of 1988 by the CDC. The numbers of cases actually reported in each category are shown in Table 6.

TABLE 4

PROJECTION TO ULTIMATE OF AIDS CASES DIAGNOSED IN 1984

Report Date		Number	Yearly	Percentage of Total	
Year	Quarter	of Cases	Totals	Year	Cumulative
1984	1	347		5.7%	5.7%
	2	916		15.2	20.9
	3	1,059		17.5	38.4
	4	1,352	3,674	22.4	60.8
1985	1	938		15.5	76.3
	2	359		5.9	82.2
	3	183		3.0	85.3
	4	105	1,585	1.7	87.0
1986	1	72		1.2	88.2
	2	57		0.9	89.1
	3	47		0.8	89.9
	4	34	210	0.6	90.5
1987	1	64		1.1	91.5
	2	47		0.8	92.3
	3	24		0.4	92.7
	4	72	207	1.2	93.9
1988	1	39		0.6	94.5
	2	30		0.5	95.0
	3	60		1.0	96.0
	4	30 *	159	0.5	96.5
1989	1	30 *		0.5	97.0
	2	30 *		0.5	97.5
	3	25 *		0.4	97.9
	4	25 *	110	0.4	98.3
1990	1	20 *		0.3	98.7
	2	20 *		0.3	99.0
	3	15 *		0.2	99.3
	4	15 *	70	0.2	99.5
1991	1	10 *		0.2	99.7
	2	10 *		0.2	99.8
	3	5 *		0.1	99.9
	4	5 *	30	0.1	100.0
Total		6,045	6,045		

* Indicates projected.

TABLE 5

SUMMARY OF AGING FACTORS

Percentage of Total Cases Reported by End of Third Quarter of Year	Based on 1984 Data	Actually Used
n	38.4%	35.0%
$n+1$	85.3	80.0
$n+2$	89.9	88.0
$n+3$	92.7	92.0
$n+4$	96.0	96.0
$n+5$	97.9	97.9
$n+6$	99.3	99.3
$n+7$	99.9	99.9

TABLE 6

AIDS CASES BY DATE OF DIAGNOSIS

Classification	Reported through September 30, 1988				
	White	Black	Hispanic	Other	Total
Diagnosed in 1981 and Prior					
Homosexual male	175	34	25	1	235
Bisexual male	6	3	0	0	9
Male IV drug user	8	13	11	0	32
Female IV drug user	1	4	5	1	11
Homosexual and IV drug user	13	4	3	0	20
Bisexual and IV drug user	1	2	1	0	4
Heterosexual male	0	0	0	0	0
Heterosexual female	0	1	1	0	2
Male born outside U.S.	0	21	0	0	21
Female born outside U.S.	0	3	0	0	3
Male undetermined	6	0	3	0	9
Female undetermined	3	2	0	1	6
Total	213	87	49	3	352
Diagnosed in 1982					
Homosexual male	446	99	54	3	602
Bisexual male	16	15	4	0	35
Male IV drug user	35	64	48	1	148
Female IV drug user	7	22	6	0	35
Homosexual and IV drug user	43	23	17	0	83
Bisexual and IV drug user	3	5	2	1	11
Heterosexual male	0	2	0	0	2
Heterosexual female	1	4	6	0	11
Male born outside U.S.	0	45	1	0	46
Female born outside U.S.	0	7	0	0	7
Male undetermined	12	8	2	0	22
Female undetermined	3	4	1	0	8
Total	566	298	141	5	1,010
Diagnosed in 1983					
Homosexual male	1,164	178	170	11	1,523
Bisexual male	148	76	21	2	247
Male IV drug user	72	195	129	2	398
Female IV drug user	30	53	30	2	115
Homosexual and IV drug user	142	33	25	2	202
Bisexual and IV drug user	32	25	15	0	72
Heterosexual male	0	1	0	0	1
Heterosexual female	5	12	8	1	26
Male born outside U.S.	1	85	1	0	87
Female born outside U.S.	0	16	0	0	16
Male undetermined	13	25	14	2	54
Female undetermined	5	9	3	0	17
Total	1,612	708	416	22	2,758

TABLE 6—*Continued*

Classification	Reported through September 30, 1988				
	White	Black	Hispanic	Other	Total
Diagnosed in 1984					
Homosexual male	2,436	377	317	24	3,154
Bisexual male	349	145	63	5	562
Male IV drug user	135	402	240	2	779
Female IV drug user	46	105	48	0	199
Homosexual and IV drug user	270	70	52	1	393
Bisexual and IV drug user	54	39	22	0	115
Heterosexual male	6	12	1	0	19
Heterosexual female	11	31	21	0	63
Male born outside U.S.	1	108	0	0	109
Female born outside U.S.	0	23	0	0	23
Male undetermined	41	39	14	2	96
Female undetermined	6	23	4	0	33
Total	3,355	1,374	782	34	5,545
Diagnosed in 1985					
Homosexual male	4,401	721	604	47	5,773
Bisexual male	662	289	129	11	1,091
Male IV drug user	255	768	462	5	1,490
Female IV drug user	78	226	86	7	397
Homosexual and IV drug user	367	111	78	4	560
Bisexual and IV drug user	110	74	34	0	218
Heterosexual male	9	21	3	1	34
Heterosexual female	41	77	50	0	168
Male born outside U.S.	1	126	0	0	127
Female born outside U.S.	0	39	1	0	40
Male undetermined	69	59	39	5	172
Female undetermined	15	24	8	0	47
Total	6,008	2,535	1,494	80	10,117
Diagnosed in 1986					
Homosexual male	6,805	1,126	869	87	8,887
Bisexual male	1,062	502	214	21	1,799
Male IV drug user	421	1,113	788	12	2,334
Female IV drug user	137	387	116	3	643
Homosexual and IV drug user	634	179	106	4	923
Bisexual and IV drug user	193	103	64	0	360
Heterosexual male	23	41	9	0	73
Heterosexual female	91	153	79	3	326
Male born outside U.S.	0	169	1	0	170
Female born outside U.S.	0	57	1	1	59
Male undetermined	128	129	61	10	328
Female undetermined	28	43	16	1	88
Total	9,522	4,002	2,324	142	15,990

TABLE 6—*Continued*

Classification	Reported through September 30, 1988				
	White	Black	Hispanic	Other	Total
Diagnosed in 1987					
Homosexual male	8,766	1,530	1,092	118	11,506
Bisexual male	1,519	696	285	30	2,530
Male IV drug user	713	1,696	1,096	12	3,517
Female IV drug user	257	631	190	6	1,084
Homosexual and IV drug user	663	268	134	7	1,072
Bisexual and IV drug user	219	152	83	3	457
Heterosexual male	77	92	23	1	193
Heterosexual female	149	250	131	3	533
Male born outside U.S.	1	211	1	0	213
Female born outside U.S.	0	75	1	0	76
Male undetermined	265	228	160	8	661
Female undetermined	47	67	23	3	140
Total	12,676	5,896	3,219	191	21,982
Diagnosed in 1988					
Homosexual male	4,878	982	671	72	6,603
Bisexual male	852	410	161	22	1,445
Male IV drug user	483	1,136	734	10	2,363
Female IV drug user	135	426	130	1	692
Homosexual and IV drug user	356	147	66	2	571
Bisexual and IV drug user	115	105	47	2	269
Heterosexual male	60	61	19	0	140
Heterosexual female	113	173	95	7	388
Male born outside U.S.	0	104	1	3	108
Female bore outside U.S.	0	51	0	0	51
Male undetermined	226	191	123	6	546
Female undetermined	33	61	28	3	125
Total	7,251	3,847	2,075	128	13,301
Total					
Homosexual male	29,071	5,047	3,802	363	38,283
Bisexual male	4,614	2,136	877	91	7,718
Male IV drug user	2,122	5,387	3,508	44	11,061
Female IV drug user	691	1,854	611	20	3,176
Homosexual and IV drug user	2,488	835	481	20	3,824
Bisexual and IV drug user	727	505	268	6	1,506
Heterosexual male	175	230	55	2	462
Heterosexual female	411	701	391	14	1,517
Male born outside U.S.	4	869	5	3	881
Female born outside U.S.	0	271	3	1	275
Male undetermined	760	679	416	33	1,888
Female undetermined	140	233	83	8	464
Total	41,203	18,747	10,500	605	71,055

Next, the aging factors from Table 5 were applied to the figures shown in Table 6 to estimate the number of AIDS cases that will ultimately be reported for each calendar year through 1988. These figures are shown in Table 7.

Reclassification of Homosexual/Bisexuals Who Also Use IV Drugs, Persons Born Outside the U.S., and "Undetermined" Group

Because the model does not have a special category for those homosexuals and bisexuals who also use IV drugs, it was necessary to reclassify them as either homosexual/bisexual or as IV drug users. Similarly, it was necessary to reclassify those born outside the U.S. and the "undetermined" group.

The reclassification of the homosexuals/bisexuals who also were IV drug users was done based on the racial characteristics of the several groups. As the final section of Table 7 shows, 4,482 of the 7,542 persons in this classification, or 59.4 percent, are white. By comparison, 48,558 of 66,708, or 72.8 percent, of the homosexual and bisexual males are white, while only 3,284 of 16,189, or 19.5 percent, of male IV drug users are white. Thus the homosexuals and bisexuals who are also IV drug users exhibit a racial split significantly closer to that of homosexuals and bisexuals than that of IV drug users. Therefore, 80 percent of this group was allocated to the homosexual or bisexual classification, and the remaining 20 percent to the IV drug classification.

With regard to persons born outside the U.S., the CDC has generally included them with the "heterosexual transmission" group, because the locations involved (Haiti and central Africa) have a significant amount of heterosexual transmission. However, the data do not appear to support this approach for purposes of the modeling process. Males constitute 1,176 of 1,578, or 74.5 percent, of these cases. This is very close to the ratio of males to total for IV drug cases, where males constitute 16,819 of 21,684, or 77.6 percent, of the cases. On the other hand, males only constitute 784 of 3,217, or 24.3 percent, of heterosexual transmission cases. For this reason, these cases were reallocated, somewhat arbitrarily, as follows:

Classification	Male	Female
Homosexual	20%	NA
Bisexual	5	NA
IV drug user	50	50%
Heterosexual transmission	25	50

TABLE 7

AIDS CASES BY DATE OF DIAGNOSIS—PROJECTED TO ULTIMATE

Classification	Estimated Percentage Reported	Ultimate				
		White	Black	Hispanic	Other	Total
Diagnosed in 1981 and Prior						
Homosexual male	99.9%	175	34	25	1	235
Bisexual male		6	3	0	0	9
Male IV drug user		8	13	11	0	32
Female IV drug user		1	4	5	1	11
Homosexual and IV drug user		13	4	3	0	20
Bisexual and IV drug user		1	2	1	0	4
Heterosexual male		0	0	0	0	0
Heterosexual female		0	1	1	0	2
Male born outside U.S.		0	21	0	0	21
Female born outside U.S.		0	3	0	0	3
Male undetermined		6	0	3	0	9
Female undetermined		3	2	0	0	1
Total		213	87	49	3	352
Diagnosed in 1982						
Homosexual male	99.3%	449	100	54	3	606
Bisexual male		16	15	4	0	35
Male IV drug user		35	64	48	1	149
Female IV drug user		7	22	6	0	35
Homosexual and IV drug user		43	23	17	0	84
Bisexual and IV drug user		3	5	2	1	11
Heterosexual male		0	2	0	0	2
Heterosexual female		1	4	6	0	11
Male born outside U.S.		0	45	1	0	46
Female born outside U.S.		0	7	0	0	7
Male undetermined		12	8	2	0	22
Female undetermined		3	4	1	0	8
Total		570	300	142	5	1,017
Diagnosed in 1983						
Homosexual male	97.9%	1,189	182	174	11	1,556
Bisexual male		151	78	21	2	252
Male IV drug user		74	199	132	2	407
Female IV drug user		31	54	31	2	117
Homosexual and IV drug user		145	34	26	2	206
Bisexual and IV drug user		33	26	15	0	74
Heterosexual male		0	1	0	0	1
Heterosexual female		5	12	8	1	27
Male born outside U.S.		1	87	1	0	89
Female born outside U.S.		0	16	0	0	16
Male undetermined		13	26	14	2	55
Female undetermined		5	9	3	0	17
Total		1,647	723	425	22	2,817

TABLE 7—*Continued*

Classification	Estimated Percentage Reported	Ultimate				
		White	Black	Hispanic	Other	Total
Diagnosed in 1984						
Homosexual male	96.0%	2,538	393	330	25	3,285
Bisexual male		364	151	66	5	585
Male IV drug user		141	419	250	2	811
Female IV drug user		48	109	50	0	207
Homosexual and IV drug user		281	73	54	1	409
Bisexual and IV drug user		56	41	23	0	120
Heterosexual male		6	13	1	0	20
Heterosexual female		11	32	22	0	66
Male born outside U.S.		1	113	0	0	114
Female born outside U.S.		0	24	0	0	24
Male undetermined		43	41	15	2	100
Female undetermined		6	24	4	0	34
Total		3,495	1,431	815	35	5,776
Diagnosed in 1985						
Homosexual male	92.0%	4,784	784	657	51	6,275
Bisexual male		720	314	140	12	1,186
Male IV drug user		277	835	502	5	1,620
Female IV drug user		85	246	93	8	432
Homosexual and IV drug user		399	121	85	4	609
Bisexual and IV drug user		120	80	37	0	237
Heterosexual male		10	23	3	1	37
Heterosexual female		45	84	54	0	183
Male born outside U.S.		1	137	0	0	138
Female born outside U.S.		0	42	1	0	43
Male undetermined		75	64	42	5	187
Female undetermined		16	26	9	0	51
Total		6,530	2,755	1,624	87	10,997
Diagnosed in 1986						
Homosexual male	88.0%	7,733	1,280	988	99	10,099
Bisexual male		1,207	570	243	24	2,044
Male IV drug user		478	1,265	895	14	2,652
Female IV drug user		156	440	132	3	731
Homosexual and IV drug user		720	203	120	5	1,049
Bisexual and IV drug user		219	117	73	0	409
Heterosexual male		26	47	10	0	83
Heterosexual female		103	174	90	3	370
Male born outside U.S.		0	192	1	0	193
Female born outside U.S.		0	65	1	1	67
Male undetermined		145	147	69	11	373
Female undetermined		32	49	18	1	100
Total		10,820	4,548	2,641	161	18,170

TABLE 7—*Continued*

Classification	Estimated Percentage Reported	Ultimate				
		White	Black	Hispanic	Other	Total
Diagnosed in 1987						
Homosexual male	80.0%	10,958	1,913	1,365	148	14,383
Bisexual male		1,899	870	356	38	3,163
Male IV drug user		891	2,120	1,370	15	4,396
Female IV drug user		321	789	238	8	1,355
Homosexual and IV drug user		829	335	168	9	1,340
Bisexual and IV drug user		274	190	104	4	571
Heterosexual male		96	115	29	1	241
Heterosexual female		186	313	164	4	666
Male born outside U.S.		1	264	1	0	266
Female born outside U.S.		0	94	1	0	95
Male undetermined		331	285	200	10	826
Female undetermined		59	84	29	4	175
Total		15,845	7,370	4,024	239	27,478
Diagnosed in 1988						
Homosexual male	35.0%	13,937	2,806	1,917	206	18,866
Bisexual male		2,434	1,171	460	63	4,129
Male IV drug user		1,380	3,246	2,097	29	6,751
Female IV drug user		386	1,217	371	3	1,977
Homosexual and IV drug user		1,017	420	189	6	1,631
Bisexual and IV drug user		329	300	134	6	769
Heterosexual male		171	174	54	0	400
Heterosexual female		323	494	271	20	1,109
Male born outside U.S.		0	297	3	9	309
Female born outside U.S.		0	146	0	0	146
Male undetermined		646	546	351	17	1,560
Female undetermined		94	174	80	9	357
Total		20,717	10,991	5,929	366	38,003
Total						
Homosexual male		41,762	7,490	5,509	543	55,305
Bisexual male		6,796	3,173	1,291	143	11,403
Male IV drug user		3,284	8,161	5,306	68	16,819
Female IV drug user		1,034	2,881	926	24	4,865
Homosexual and IV drug user		3,448	1,213	661	26	5,348
Bisexual and IV drug user		1,034	761	389	10	2,194
Heterosexual male		310	374	98	2	784
Heterosexual female		675	1,114	616	28	2,433
Male born outside U.S.		4	1,156	7	9	1,176
Female born outside U.S.		0	397	3	1	402
Male undetermined		1,271	1,116	697	48	3,132
Female undetermined		219	372	144	14	749
Total		59,838	28,206	15,648	919	104,610

The AIDS cases by date of diagnosis, projected to ultimate after reallocation of the above classifications, are shown in Table 8.

Total Population

The total population used for 1982 was the U.S. population age 16 and over, as reported by the Bureau of the Census. This was split according to race by using racial percentages shown in the CDC's *Morbidity and Mortality Weekly Report* [1]. The resulting population figures for 1982 were as follows:

Race	Male	Female	Total
White	69,163,000	75,197,000	144,360,000
Black	9,006,000	9,792,000	18,798,000
Other	6,797,000	7,390,000	14,187,000
Total	84,967,000	92,380,000	177,346,000

Percent of Population That Is Homosexual, Bisexual, and IV Drug Users

In order to operate the model, the percentages of the population that are homosexual, bisexual, and users of IV drugs must be estimated. These estimates must be split by race and (in the case of IV drug users) by sex.

The estimates for the total number of persons in these categories were based on Table 14 of a 1987 CDC report [4]. This table shows the following figures:

Category	Estimated Size
Exclusively homosexual throughout life	2,500,000
Other homosexual contact including highly infrequent	2,500,000–7,500,000
Regular (at least weekly) IV drug use	900,000
Occasional IV drug use	200,000

The estimate of the homosexual population was based on the 1948 study by Kinsey et al. [1], combined with 1980 census data. The estimate of the IV drug population was based on 1987 data from the National Institute on Drug Abuse and excludes persons who have used drugs only once or twice.

Based on the above estimates, it was decided to assume that there were 2,500,000 homosexuals and 2,000,000 bisexuals in 1982 and that there were 1,000,000 IV drug users in 1987. These estimates assume that many of those

TABLE 8

AIDS CASES BY DATE OF DIAGNOSIS—ULTIMATE AFTER REALLOCATION

Classification	White	Black	Hispanic	Other	Total
Diagnosed in 1981 and Prior					
Homosexual male	191	41	30	1	263
Bisexual male	7	6	1	0	13
Male IV drug user	11	25	13	0	49
Female IV drug user	4	7	5	2	18
Heterosexual male	0	5	0	0	5
Heterosexual female	0	3	1	0	4
Total	213	87	49	3	352
Diagnosed in 1982					
Homosexual male	495	132	69	3	699
Bisexual male	19	22	6	1	48
Male IV drug user	45	96	54	1	196
Female IV drug user	10	29	7	0	45
Heterosexual male	0	13	0	0	14
Heterosexual female	1	8	7	0	16
Total	570	300	142	5	1,017
Diagnosed in 1983					
Homosexual male	1,316	236	202	14	1,769
Bisexual male	179	107	35	2	323
Male IV drug user	110	266	146	3	525
Female IV drug user	35	70	33	2	140
Heterosexual male	0	23	0	0	23
Heterosexual female	6	22	9	1	38
Total	1,647	723	425	22	2,817
Diagnosed in 1984					
Homosexual male	2,798	490	381	27	3,697
Bisexual male	414	195	85	6	700
Male IV drug user	211	515	271	2	999
Female IV drug user	53	140	53	0	246
Heterosexual male	7	41	1	0	49
Heterosexual female	13	50	23	0	86
Total	3,495	1,431	815	35	5,776
Diagnosed in 1985					
Homosexual male	5,165	933	746	59	6,903
Bisexual male	825	396	174	13	1,407
Male IV drug user	385	971	543	7	1,905
Female IV drug user	95	286	100	8	489
Heterosexual male	10	58	3	1	73
Heterosexual female	50	112	58	0	220
Total	6,530	2,755	1,624	87	10,997
Diagnosed in 1986					
Homosexual male	8,428	1,540	1,116	111	11,195
Bisexual male	1,401	700	309	26	2,436
Male IV drug user	674	1,484	964	16	3,137
Female IV drug user	175	507	143	5	830
Heterosexual male	27	97	11	0	134
Heterosexual female	116	220	98	5	438
Total	10,820	4,548	2,641	161	18,170

TABLE 8—*Continued*

Classification	White	Black	Hispanic	Other	Total
			Diagnosed in 1987		
Homosexual male	11,883	2,342	1,587	162	15,973
Bisexual male	2,163	1,085	462	42	3,752
Male IV drug user	1,134	2,477	1,513	18	5,142
Female IV drug user	358	896	255	10	1,519
Heterosexual male	99	187	31	1	319
Heterosexual female	208	383	176	5	772
Total	15,845	7,370	4,024	239	27,478
			Diagnosed in 1988		
Homosexual male	15,253	3,408	2,217	224	21,102
Bisexual male	2,785	1,513	603	71	4,972
Male IV drug user	1,699	3,778	2,326	37	7,839
Female IV drug user	437	1,414	418	4	2,273
Heterosexual male	178	261	59	2	500
Heterosexual female	366	617	305	28	1,316
Total	20,717	10,991	5,929	366	38,003
			Total		
Homosexual male	45,539	9,126	6,354	601	61,621
Bisexual male	7,790	4,024	1,676	161	13,650
Male IV drug user	4,263	9,607	5,823	84	19,777
Female IV drug user	1,166	3,348	1,014	32	5,560
Heterosexual male	319	685	105	5	1,113
Heterosexual female	761	1,416	676	36	2,889
Total	59,838	28,206	15,648	919	104,610

who had homosexual contact, but were not exclusively homosexual, did not go so far as to engage in high-risk activity (that is, anal sex). They also assume that only half of those who were occasional IV drug users were subject to the risks associated with sharing needles.

Because the above estimates were not split by sex or race, it was necessary to do so. In the absence of any other information, this split was done in proportion to the total number of AIDS cases shown in Table 8. Then percentages (to the nearest hundredth of a percent) were applied to the total 1982 population figures to reproduce the estimated homosexual and bisexual populations in 1982 and to reproduce the estimated IV-drug-using population in 1987, split by race and sex. The resulting percentages and population figures are shown in Table 9. (Note that here and throughout the results presented by the model, hispanics and other races are combined into one category titled "other.")

TABLE 9

ALLOCATION OF HOMOSEXUALS, BISEXUALS, AND IV DRUG USERS BY RACE

Classification	Percentage of Population	Number of Persons
Homosexual Males		
White	2.67%	1,847,000
Black	4.11	370,000
Other	4.15	282,000
Total		2,499,000
Bisexual Males		
White	1.65	1,141,000
Black	6.55	590,000
Other	3.96	269,000
Total		2,000,000
IV Drug Users		
Male, white	0.23	168,000
Male, black	3.96	380,000
Male, other	3.22	233,000
Female, white	0.06	47,000
Female, black	1.27	134,000
Female, other	0.52	41,000
Total		1,000,000

It was arbitrarily assumed that 1 percent of the female population is homosexual (that is, lesbian). Note that, because the model assumes that AIDS does not transmit by female homosexual activity, this assumption merely has the effect of removing 1 percent of the female population from the group of people who can become infected by sexual activity.

Other Assumptions

Several other assumptions are necessary to operate the model, including:

1. The number of unprotected acts per year by a person of:
   a. IV drug use (that is, sharing needles)
   b. Anal intercourse, homosexual
   c. Anal intercourse, bisexual
   d. Anal intercourse, female heterosexual
   e. Vaginal intercourse.
2. The number of persons infected in 1981, by category.
3. The year in which those infected in 1981 became infected.

Relatively little is known about any of these numbers, and in fact their very definition is subject to interpretation in some cases. For example, is sexual activity between two persons who have been monogamous all their lives considered to be "unprotected" sexual activity?

Fortunately, as discussed earlier, the approach used in the model does not require that these parameters be known. Instead, it develops them by using a trial-and-error process, once the other assumptions described previously have been determined. Starting with an assumed number and distribution of infections in 1981, the number of new infections each year is determined for each category by application of the frequencies of each act, the probability of infection from doing the act with an infected person, and the probability that the person will be infected from a single act, using the formulas described earlier. Then the number of AIDS cases and deaths is calculated for each category by application of the progression rates described above, combined with the fatality rates developed from the CDC data. By using the trial-and-error process, the number of 1981 infections and the sexual and drug frequencies are set so that the resulting AIDS cases and deaths come as close as possible to the actual number of such cases and deaths for each category.

The trial-and-error process produced a set of assumptions that in turn was able to develop modeled AIDS cases within 1 percent of the actual cases projected to ultimate by date of diagnosis as shown in Tables 7 and 8.

The assumptions so developed are shown in Tables 10, 11 and 12. A comparison of the modeled cases with the actual cases shown in Table 8 is shown by risk category in Table 13 and by race in Table 14.

TABLE 10

NUMBER OF PERSONS WITH HIV INFECTION IN 1981

	Homosexual	Bisexual	IV Drug User	Drug-Free Heterosexual	Total
Male					
White	44,000	6,000	4,000	400	54,400
Black	7,300	4,200	7,200	1,000	19,700
Other	6,300	1,800	4,400	400	12,900
Female					
White			600	100	700
Black			2,600	700	3,300
Other			900	250	1,150
Total	57,600	12,000	19,700	2,850	92,150

Table 12 shows that a considerable decrease has already taken place in high-risk homosexual and bisexual activity and that some reductions have already taken place in IV drug use and heterosexual activity. As already discussed, the principal basis for these assumptions is the validation process itself. In addition, various recent surveys have suggested some reduction in

TABLE 11

DISTRIBUTION BY YEAR OF INFECTION FOR PERSONS INFECTED IN 1981

Year	Percentage of 1981 Infections
1977	1%
1978	2
1979	7
1980	20
1981	70

TABLE 12

"AVERAGE" NUMBER OF UNPROTECTED SEXUAL AND IV DRUG ACTS PER YEAR

Year	IV Drug Use	Receptive Anal Intercourse			Penile-Vaginal Intercourse
		Homosexual	Bisexual	Female	
to 1982	55	130	50	0.5	50
1983	54	105	35	0.5	50
1984	53	80	20	0.5	50
1985	51	55	15	0.5	50
1986	48	30	10	0.5	47.5
1987	45	20	7.5	0.5	45
1988	40	10	5	0.5	42.5

sexual and IV drug activity. The most significant survey appeared in the form of a chart in the 1987 CDC report [4]. This chart, which is reproduced as Chart 1, shows that, according to a number of cohort studies, since 1982 there has been a sharp drop in new HIV infections among homosexual men.

Several comments should be made about the comparison between the CDC figures and those developed by the model:

1. *Overall Comparison.* In total, the modeled AIDS cases are 101 percent of the cases based on CDC data. The model and the CDC data compare fairly closely in total for 1985 through 1988, with the model developing AIDS cases equal to 97 percent, 98 percent, 99 percent, and 103 percent of the CDC cases for those years, respectively. However, for 1984 the modeled figures are 106 percent of the actual, and for 1982 and 1983 they are 170 percent and 120 percent, respectively. The trial-and-error process demonstrated that it was not possible to come closer to the CDC numbers for 1983 and prior by using reasonable assumptions, without causing the modeled results for 1984 and subsequent to deviate significantly from the CDC numbers. The author's conclusion is that, prior to 1984, there was significantly more undercounting of AIDS cases than is currently the case and that the model would track the CDC data more closely if it were somehow possible to include such cases in the data for 1983 and prior. This conclusion is supported by the fact that the model shows 170 percent of the CDC numbers for 1982, but only 120 percent of

TABLE 13

COMPARISON BY RISK CATEGORY OF MODELED AIDS CASES WITH ACTUAL CASES AS SHOWN IN TABLE 8

Category	Number of Cases		Difference: Model to Actual	
	Modeled	Actual	Percentage	Number
Diagnosed in 1981 and Prior				
Homosexual male	NA	263	NA	NA
Bisexual male	NA	13	NA	NA
Male IV drug user	NA	49	NA	NA
Female IV drug user	NA	18	NA	NA
Heterosexual male	NA	5	NA	NA
Heterosexual female	NA	4	NA	NA
Total	NA	352	NA	NA
Diagnosed in 1982				
Homosexual male	1,078	699	54%	379
Bisexual male	225	48	369	177
Male IV drug user	292	196	49	96
Female IV drug user	77	45	71	32
Heterosexual male	34	14	143	20
Heterosexual female	20	16	25	4
Total	1,726	1,018	70%	708
Diagnosed in 1983				
Homosexual male	2,102	1,769	19%	333
Bisexual male	452	323	40	129
Male IV drug user	566	525	8	41
Female IV drug user	149	140	6	9
Heterosexual male	62	23	170	39
Heterosexual female	42	38	11	4
Total	3,373	2,818	20%	555
Diagnosed in 1984				
Homosexual male	3,794	3,697	3%	97
Bisexual male	857	700	22	157
Male IV drug user	1,016	999	2	17
Female IV drug user	271	246	10	25
Heterosexual male	98	49	100	49
Heterosexual female	93	86	8	7
Total	6,129	5,777	6%	352
Diagnosed in 1985				
Homosexual male	6,554	6,903	−5%	(349)
Bisexual male	1,530	1,407	9	123
Male IV drug user	1,783	1,905	−6	(122)
Female IV drug user	481	489	−2	(8)
Heterosexual male	144	73	97	71
Heterosexual female	204	220	−7	(16)
Total	10,696	10,997	−3%	(301)
Diagnosed in 1986				
Homosexual male	10,723	11,195	−4%	(472)
Bisexual male	2,529	2,436	4	93
Male IV drug user	3,077	3,137	−2	(60)
Female IV drug user	840	830	1	10
Heterosexual male	207	134	54	73
Heterosexual female	422	438	−4	(16)
Total	17,798	18,170	−2%	(372)

TABLE 13—*Continued*

Category	Number of Cases		Difference: Model to Actual	
	Modeled	Actual	Percentage	Number
		Diagnosed in 1987		
Homosexual male	15,914	15,973	0%	(59)
Bisexual Male	3,779	3,752	1	27
Male IV drug user	5,044	5,142	−2	(98)
Female IV drug user	1,391	1,519	−8	(128)
Heterosexual male	282	319	−12	(37)
Heterosexual female	800	772	4	28
Total	27,210	27,477	−1%	(267)
		Diagnosed in 1988		
Homosexual male	21,778	21,102	3%	676
Bisexual male	5,245	4,972	5	273
Male IV drug user	7,948	7,839	1	109
Female IV drug user	2,211	2,273	−3	(62)
Heterosexual male	373	500	−25	(127)
Heterosexual female	1,412	1,316	7	96
Total	38,967	38,002	3%	965
		Total		
Homosexual male	61,943	61,601	1%	342
Bisexual male	14,617	13,651	7	966
Male IV drug user	19,726	19,792	0	(66)
Female IV drug user	5,420	5,560	−3	(140)
Heterosexual male	1,200	1,117	7	83
Heterosexual female	2,993	2,890	4	103
Total	105,899	104,611	1%	1,288

the CDC numbers for 1983. Also, the number of cases involved for those early years is much smaller than current levels, and so the percentage error is of less consequence.

2. *Comparison by Risk Category*. The model fairly accurately reproduces the actual cases for homosexuals and IV drug users, the overall ratios being 101 percent and 99 percent, respectively. However, the model overstates the number of cases for bisexual males by 7 percent, most of which occurs in the earlier years. The model fairly accurately reproduces the number of heterosexual contact cases for 1986 through 1988 in total; however, the number of modeled cases for heterosexual males is significantly higher than the actual cases in the early years and significantly lower in the later years. The actual male heterosexual cases could not be reproduced more accurately without significantly overstating the female heterosexual cases. The author's conclusion is that some of the cases being reported as male heterosexual transmission may in fact be from IV drug use or homosexual activity.
3. *Comparison by Race*. The model's accuracy in reproducing the actual data by racial group is only moderately successful. Overall, the modeled cases for whites are 7

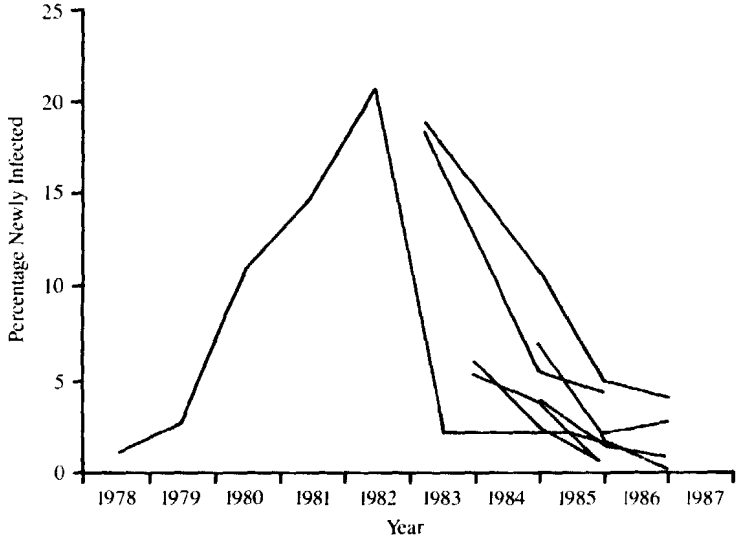
TABLE 14

COMPARISON BY RACE OF MODELED AIDS CASES WITH ACTUAL CASES AS SHOWN IN TABLE 8

Category	Number of Cases		Difference: Model to Actual	
	Modeled	Actual	Percentage	Number
Diagnosed in 1981 and Prior				
White	NA	213	NA	NA
Black	NA	87	NA	NA
Other	NA	52	NA	NA
Total	NA	352	NA	NA
Diagnosed in 1982				
White	1,031	570	81%	461
Black	430	300	43	130
Other	263	147	79	116
Total	1,724	1,017	70%	707
Diagnosed in 1983				
White	2,026	1,647	23%	379
Black	834	723	15	111
Other	512	447	15	65
Total	3,372	2,817	20%	555
Diagnosed in 1984				
White	3,718	3,495	6%	223
Black	1,487	1,431	4	56
Other	925	850	9	75
Total	6,130	5,776	6%	354
Diagnosed in 1985				
White	6,544	6,530	0%	14
Black	2,547	2,755	−8	(208)
Other	1,607	1,711	−6	(104)
Total	10,698	10,996	−3%	(298)
Diagnosed in 1986				
White	10,909	10,820	1%	89
Black	4,206	4,548	−8	(342)
Other	2,682	2,802	−4	(120)
Total	17,797	18,170	−2%	(373)
Diagnosed in 1987				
White	16,569	15,845	5%	724
Black	6,483	7,370	−12	(887)
Other	4,157	4,263	−2	(106)
Total	27,209	27,478	−1%	(269)
Diagnosed in 1988				
White	23,363	20,717	13%	2,646
Black	9,508	10,991	−13	(1,483)
Other	6,095	6,295	−3	(200)
Total	38,966	38,003	3%	963
Total				
White	64,160	59,837	7%	4,323
Black	25,495	28,205	−10	(2,710)
Other	16,241	16,567	−2	(326)
Total	105,896	104,609	1%	1,287

CHART 1

HIV INCIDENCE (PERCENTAGE OF UNINFECTED MEN BECOMING INFECTED) IN EIGHT COHORT STUDIES OF HOMOSEXUAL MEN, BY YEAR, UNITED STATES, 1978-1987



percent above the actual, while the modeled cases for blacks are 10 percent below the actual. An examination of the results for 1984–1988 shows that the difference between the white and black deviations is only 2 percent in 1984, then increases to 8 percent in 1985, 9 percent in 1986, 17 percent in 1987, and finally to 26 percent in 1988. This suggests that there are significant racial differences in the frequencies of sexual and IV drug activity and that AIDS educational efforts may have been more effective with whites than with blacks. (For further evidence and discussion of this point, see the discussion in Section VI on variations in incidence in HIV infection by race.)

The model is fully capable of varying any of the assumptions by race. However, without better data, the author was reluctant to postulate such racial differences in this paper. Furthermore, because most of the projections presented do not differentiate by race, such racial differences should make little difference in the results in most cases.

V. PROJECTIONS OF AIDS EPIDEMIC AND EFFECT OF BEHAVIORAL CHANGES

In Section III the model was described in detail, and in Section IV the assumptions were developed to reproduce as nearly as possible the actual results to date as reported by the CDC, adjusted for reporting lag. In this section, projections under several behavioral scenarios are presented.

At present, efforts are being made to persuade people to modify their sexual and IV drug habits in order to curb the epidemic. However, so far no one really knows how effective these educational efforts will be. The model can test the effect of any set of behavioral trends—it is just a matter of putting in the assumed frequencies of sexual and IV drug contacts, setting the "knowledge factors" and the "discrimination factors," and making any other special adjustments that might be desired. The model is designed to vary these assumed frequencies by individual years beginning in 1982 and to vary the knowledge and discrimination factors by individual years beginning in 1987.

The projections are as follows:

1. Three "basic" projections through the year 2000. These consist of "low," "middle," and "high" projections. The high projection assumes that the levels of sexual and IV drug activity calculated in the validation process continue at 1988 levels. The middle projection assumes that there is a reasonable amount of additional decrease in sexual and IV drug activity, particularly high-risk activity. The low projection assumes that there are substantial further decreases in sexual and IV drug activity, particularly high-risk activity.
2. Several projections through the year 2000, calculated by modifying the high basic projection in various ways. These projections make it possible to isolate the effect of various behavior changes and to otherwise analyze the results of the basic projections.
3. Several projections through the year 2030. Such long-range projections probably do not represent what will actually occur because of the difficulty of predicting long-term behavior trends and because of the possibility of the development of cures, vaccines, or other medical treatment. However, they are helpful in showing whether the epidemic ultimately could spread throughout the heterosexual population in the manner it already has for the high-risk groups.

The Basic Projections

The three basic projections vary only according to the assumed levels of future sexual and IV drug activity. These assumed future levels are shown in Table 15 and may be compared with the data shown in Table 12 developed during the validation process.

The application of these behavioral assumptions, together with the other parameters discussed earlier in the paper, gives the basic projections of the AIDS epidemic shown in Table 16. For convenience, the figures for prior years developed during the validation process also are shown, as are the percentage variations of the high and low projections from the middle projection.

Table 17 analyzes the basic projections by risk category.

TABLE 15

BEHAVIORAL ASSUMPTIONS USED FOR BASIC PROJECTIONS

Activity	Type of Projection	Year 1988	1989	1990	1991	1992 and Subsequent
"Average" Number of Unprotected Sexual and IV Drug Acts per Year						
IV Drug Use	Low	40	30	20	10	10
	Middle	40	35	30	25	20
	High	40	40	40	40	40
Anal Intercourse (Homosexual)	Low	10	5	2.5	2.5	2.5
	Middle	10	5	5	5	5
	High	10	10	10	10	10
Anal Intercourse (Bisexual)	Low	5	2.5	2.5	2.5	2.5
	Middle	5	2.5	2.5	2.5	2.5
	High	5	5	5	5	5
Anal Intercourse (Heterosexual)	Low	0.5	0.5	0.5	0.5	0.5
	Middle	0.5	0.5	0.5	0.5	0.5
	High	0.5	0.5	0.5	0.5	0.5
Vaginal Intercourse	Low	42.5	40	37.5	35	35
	Middle	42.5	40	40	40	40
	High	42.5	42.5	42.5	42.5	42.5
Knowledge and Discrimination Factors						
Homosexual Knowledge Factor	Low	20%	35%	50%	60%	70%
	Middle	20	30	40	50	50
	High	20	20	20	20	20
Bisexual Knowledge Factor	Low	20	35	50	60	70
	Middle	20	30	40	50	50
	High	20	20	20	20	20
IV Drug User Knowledge Factor	Low	10	20	30	45	60
	Middle	5	7.5	10	15	20
	High	5	5	5	5	5
Heterosexual Knowledge Factor	Low	10	20	30	45	60
	Middle	5	7.5	10	15	20
	High	5	5	5	5	5
Heterosexual Discrimination Factor, Bisexual	Low	10	20	30	40	50
	Middle	10	20	25	25	25
	High	10	10	10	10	10
Heterosexual Discrimination Factor, IV Drug User	Low	25	50	75	80	85
	Middle	25	50	75	75	75
	High	25	25	25	25	25

TABLE 16

BASIC PROJECTIONS OF AIDS EPIDEMIC

Year	Low Projection		Middle Projection	High Projection	
	Amount	Percentage Difference		Amount	Percentage Difference
			New HIV Infections		
1982			82,775		
1983			127,178		
1984			167,368		
1985			197,708		
1986			200,812		
1987			197,556		
1988	172,817	−2.9%	177,929	177,929	0.0%
1989	121,756	−17.2	146,965	188,745	28.4
1990	75,108	−37.2	119,642	185,836	55.3
1991	37,689	−60.3	94,955	171,762	80.9
1992	28,168	−62.0	74,098	152,732	106.1
1993	26,656	−61.0	68,401	134,375	96.5
1994	24,925	−60.2	62,568	119,478	91.0
1995	23,090	−59.5	56,971	108,383	90.2
2000	15,573	−58.1	37,184	82,011	120.6
			New AIDS Cases		
1982			1,724		
1983			3,372		
1984			6,130		
1985			10,697		
1986			17,798		
1987			27,209		
1988	38,967	0.0%	38,967	38,967	0.0%
1989	53,811	0.0	53,826	53,826	0.0
1990	70,587	−0.2	70,724	70,849	0.2
1991	86,486	−0.7	87,055	87,755	0.8
1992	99,577	−1.6	101,158	103,269	2.1
1993	108,212	−3.0	111,596	116,271	4.2
1994	111,597	−5.2	117,680	126,255	7.3
1995	110,017	−8.1	119,749	133,755	11.7
2000	68,878	−27.8	95,381	135,944	42.5

TABLE 16—*Continued*

Year	Low Projection		Middle Projection	High Projection	
	Amount	Percentage Difference		Amount	Percentage Difference
Deaths from AIDS during Year					
1982			517		
1983			1,529		
1984			3,109		
1985			5,675		
1986			9,790		
1987			15,773		
1988	23,764	0.0%	23,764	23,764	0.0%
1989	34,093	0.0	34,098	34,098	0.0
1990	46,706	−0.1	46,752	46,790	0.1
1991	60,583	−0.4	60,797	61,045	0.4
1992	74,222	−0.9	74,888	75,750	1.2
1993	86,125	−1.8	87,710	89,860	2.5
1994	95,063	−3.2	98,188	102,535	4.4
1995	100,340	−5.1	105,737	113,400	7.2
2000	82,304	−20.7	103,819	136,327	31.3
Persons Infected with HIV at End of Year					
1982			174,408		
1983			300,057		
1984			464,316		
1985			656,349		
1986			847,371		
1987			1,029,153		
1988	1,178,206	−0.4%	1,183,317	1,183,317	0.0%
1989	1,265,869	−2.3	1,296,184	1,337,964	3.2
1990	1,294,270	−5.5	1,369,075	1,477,010	7.9
1991	1,271,376	−9.4	1,403,233	1,587,727	13.1
1992	1,225,322	−12.6	1,402,443	1,664,709	18.7
1993	1,165,853	−15.7	1,383,134	1,709,224	23.6
1994	1,095,715	−18.7	1,347,514	1,726,168	28.1
1995	1,018,465	−27.2	1,298,748	1,721,150	32.5
2000	641,994	−34.1	974,461	1,514,862	55.5

TABLE 16—*Continued*

Year	Low Projection		Middle Projection	High Projection	
	Amount	Percentage Difference		Amount	Percentage Difference
			Persons with AIDS at End of Year		
1982			1,207		
1983			3,050		
1984			6,071		
1985			11,093		
1986			19,101		
1987			30,537		
1988	45,739	0.0%	45,739	45,739	0.0%
1989	65,456	0.0	65,467	65,467	0.0
1990	89,337	−0.1	89,439	89,527	0.1
1991	115,240	−0.4	115,697	116,237	0.5
1992	140,595	−1.0	141,967	143,756	1.3
1993	162,682	−1.9	165,852	170,167	2.6
1994	179,216	−3.3	185,344	193,887	4.6
1995	188,894	−5.2	199,356	214,242	7.5
2000	151,899	−21.1	192,576	254,063	31.9
			Cumulative AIDS Cases		
1982			1,724		
1983			5,096		
1984			11,226		
1985			21,923		
1986			39,721		
1987			66,930		
1988	105,897	0.0%	105,897	105,897	0.0%
1989	159,708	0.0	159,723	159,723	0.0
1990	230,295	−0.1	230,447	230,572	0.1
1991	316,781	−0.2	317,502	318,327	0.3
1992	416,358	−0.5	418,660	421,596	0.7
1993	524,570	−1.1	530,256	537,687	1.4
1994	636,167	−1.8	647,936	664,122	2.5
1995	746,184	−2.8	767,685	797,877	3.9
2000	1,176,887	−9.8	1,304,982	1,495,369	14.6

TABLE 16—*Continued*

Year	Low Projection		Middle Projection	High Projection	
	Amount	Percentage Difference		Amount	Percentage Difference
			Cumulative AIDS Deaths		
1982			517		
1983			2,046		
1984			5,155		
1985			10,830		
1986			20,620		
1987			36,393		
1988	60,157	0.0%	60,157	60,157	0.0%
1989	94,250	0.0	94,255	94,255	0.0
1990	140,956	0.0	141,007	141,045	0.0
1991	201,539	−0.1	201,804	202,090	0.1
1992	275,761	−0.3	276,692	277,840	0.4
1993	361,886	−0.7	364,402	367,700	0.9
1994	456,949	−1.2	462,590	470,235	1.7
1995	557,289	−1.9	568,327	583,635	2.7
2000	1,024,988	−7.9	1,112,406	1,241,306	11.6

Highlights of the basic projections shown in Tables 16 and 17 are as follows:

1. Under all three projections, the number of annual new HIV infections peaked in 1986 and now is on the decline. This is shown graphically in Chart 2.
2. The reason for the decline in new HIV infections has been the educational efforts within the homosexual and bisexual community. As Chart 3 shows, the number of new HIV infections in the IV drug user and heterosexual groups did not peak until 1988. Beginning in 1989, the number of new infections attributable to heterosexual transmission is projected to exceed that for homosexuals and bisexuals (although it will be far below that for IV drug users).
3. Based on the middle projection, the number of new AIDS cases will continue to rise until 1995 and then begin to decline; this is shown in Chart 4. Chart 5 shows that the number of annual AIDS deaths will peak at around 110,000 a couple of years later.
4. As of the end of 1988, there were about 1.2 million HIV+ persons. Chart 6 shows that under the middle projection, this number will peak at 1.4 million in 1991 and then decline as the annual number of AIDS deaths exceeds the number of new infections. Under the high projection, the peak will exceed 1.7 million in 1994, while under the low projection it will be about 1.3 million in 1990.

TABLE 17

ANALYSIS OF AIDS EPIDEMIC BY RISK GROUP—MIDDLE PROJECTION

Year	Homosexual/Bisexual		IV Drug User		Heterosexual		Total
	Number	Percentage	Number	Percentage	Number	Percentge	
New HIV Infections							
1982	64,535	78.0%	15,776	19.1%	2,463	3.0%	82,774
1983	95,205	74.9	27,176	21.4	4,797	3.8	127,178
1984	113,858	68.0	45,121	27.0	8,390	5.0	167,369
1985	114,595	58.0	69,785	35.3	13,327	6.7	197,707
1986	83,877	41.8	97,559	48.6	19,376	9.6	200,812
1987	58,492	29.6	116,136	58.8	22,926	11.6	197,554
1988	30,355	17.1	122,084	68.6	25,490	14.3	177,929
1989	13,525	9.2	111,320	75.7	22,120	15.1	146,965
1990	11,293	9.4	91,445	76.4	16,904	14.1	119,642
1991	8,966	9.4	68,867	72.5	17,122	18.0	94,955
1992	8,266	11.2	49,113	66.3	16,719	22.6	74,098
1993	7,507	11.0	44,024	64.4	16,870	24.7	68,401
1994	6,746	10.8	39,040	62.4	16,782	26.8	62,568
1995	6,026	10.6	34,456	60.5	16,490	28.9	56,972
1996	5,367	10.4	30,434	58.7	16,045	30.9	51,846
1997	4,778	10.1	27,035	57.1	15,503	32.8	47,316
1998	4,254	9.8	24,236	55.8	14,908	34.4	43,398
1999	3,788	9.5	21,970	54.9	14,290	35.7	40,048
2000	3,370	9.1	20,147	54.2	13,666	36.8	37,183
New AIDS Cases							
1982	1,303	75.5%	369	21.4	54	3.1%	1,726
1983	2,554	75.7	715	21.2	104	3.1	3,373
1984	4,651	75.9	1,287	21.0	191	3.1	6,129
1985	8,084	75.6	2,265	21.2	348	3.3	10,697
1986	13,252	74.5	3,917	22.0	629	3.5	17,798
1987	19,693	72.4	6,434	23.6	1,082	4.0	27,209
1988	27,023	69.3	10,159	26.1	1,785	4.6	38,967
1989	35,355	65.7	15,628	29.0	2,842	5.3	53,825
1990	43,483	61.5	22,955	32.5	4,287	6.1	70,725
1991	49,327	56.7	31,693	36.4	6,035	6.9	87,055
1992	52,010	51.4	41,190	40.7	7,958	7.9	101,158
1993	51,375	46.0	50,354	45.1	9,866	8.8	111,595
1994	48,173	40.9	57,955	49.2	11,553	9.8	117,681
1995	43,763	36.5	63,123	52.7	12,862	10.7	119,748
1996	38,921	33.0	65,438	55.4	13,723	11.6	118,082
1997	34,446	30.2	65,185	57.2	14,249	12.5	113,880
1998	30,453	28.2	63,047	58.3	14,626	13.5	108,126
1999	27,001	26.5	59,901	58.8	14,927	14.7	101,829
2000	23,880	25.0	56,363	59.1	15,139	15.9	95,382

CHART 2

COMPARISON OF BASIC PROJECTIONS
NUMBER OF NEW HIV INFECTIONS

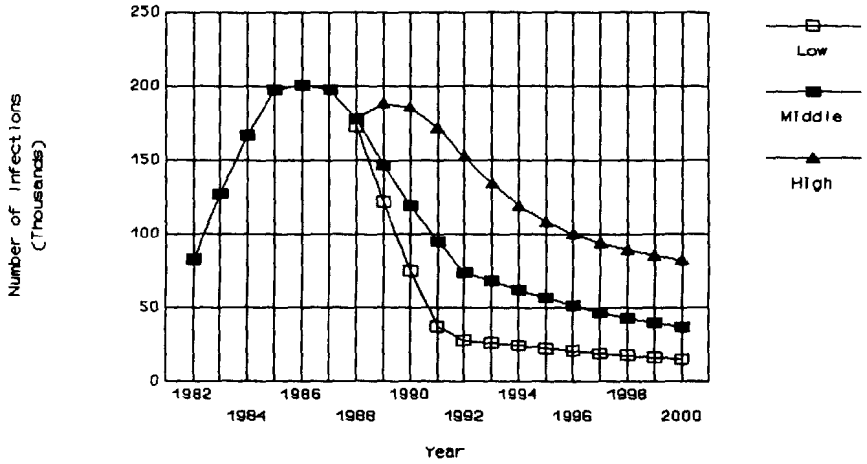


CHART 3

NUMBER OF NEW HIV INFECTIONS BY YEAR
BY RISK GROUP

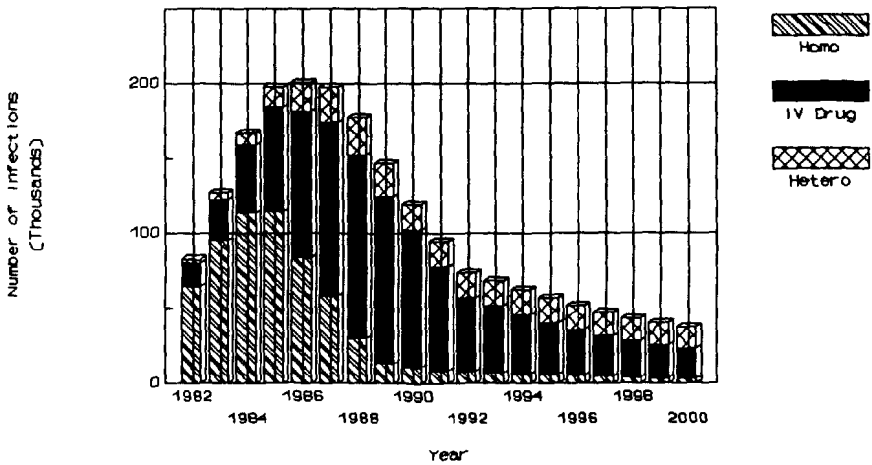


CHART 4

COMPARISON OF BASIC PROJECTIONS
NUMBER OF NEW AIDS CASES

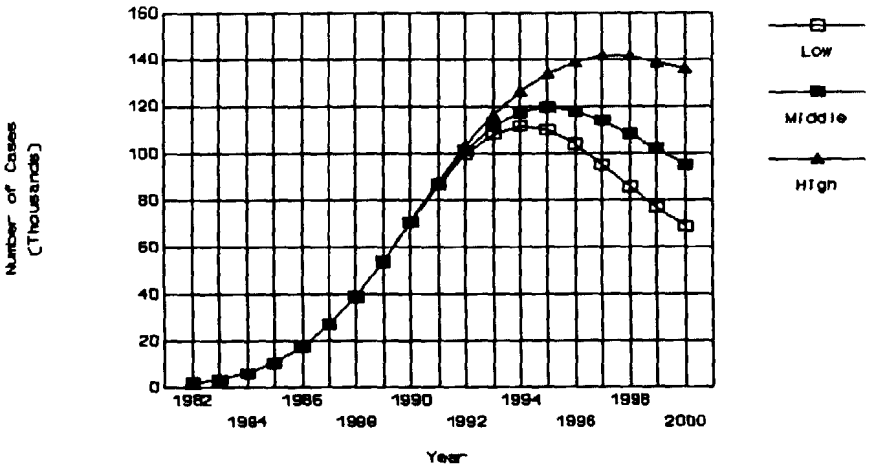


CHART 5

COMPARISON OF BASIC PROJECTIONS
NUMBER OF DEATHS FROM AIDS

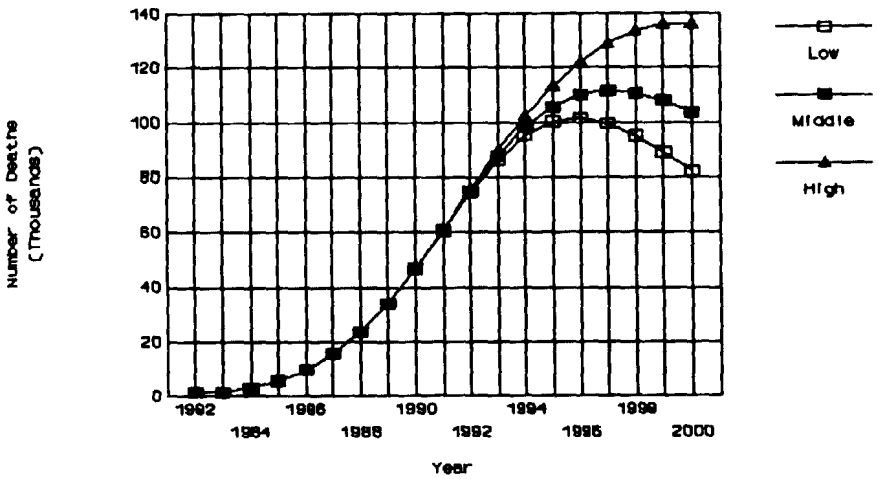
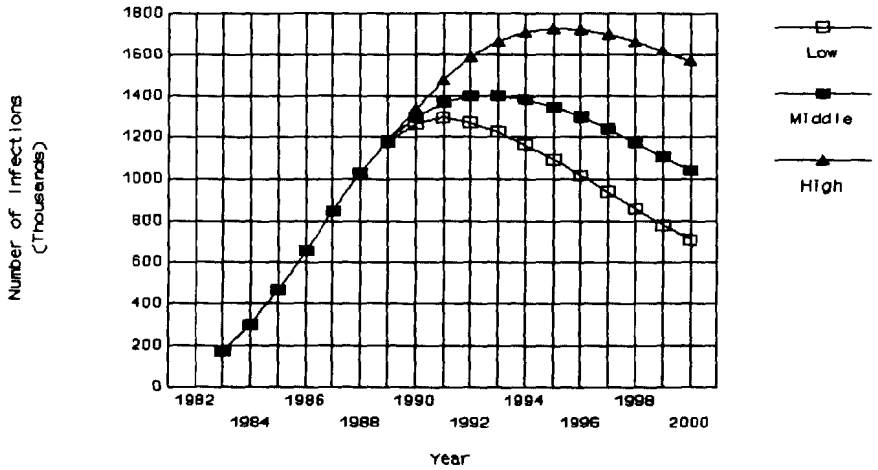


CHART 6

COMPARISON OF BASIC PROJECTIONS
NUMBER OF HIV+ PERSONS



5. Based on the middle projection, the number of persons currently with AIDS will continue to rise until 1997, at which time about 210,000 persons will have the disease, and then will begin to decline. Under the high projection, the peak will come in 1999 at about 255,000 persons; under the low projection the peak will come in 1996 at about 190,000.
6. Chart 7 shows that the cumulative number of AIDS cases diagnosed through 1991 is projected at about 318,000, with little variation among the low, middle, and high projections. (This small variation is the reason that many of those who are concerned only with projecting the epidemic through 1991 do not believe that a behavior-based modeling approach is necessary.)
7. By the year 2000, the middle projection shows that there will have been a total of about 1.3 million AIDS cases, with about 1.1 million deaths. However, by then the annual number of new HIV infections will be only about 20 percent as large as at the peak level in 1986, and the number of new AIDS cases will have been diminishing for several years.
8. Although originally most AIDS cases could be traced to homosexuals and bisexuals, Chart 8 illustrates the increasing proportion of such cases that are attributable to IV drug use. The middle projection shows that this trend will continue; it also shows that the proportion of AIDS cases attributable to heterosexual transmission will continue to rise from the present level of 5 percent to about 16 percent by the year 2000.

CHART 7

COMPARISON OF BASIC PROJECTIONS
CUMULATIVE TOTAL OF AIDS CASES

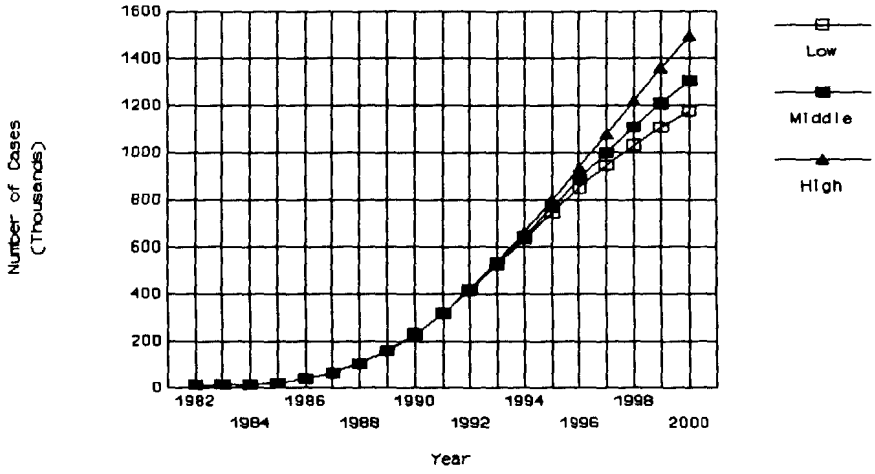


CHART 8

NUMBER OF NEW AIDS CASES
MIDDLE PROJECTION

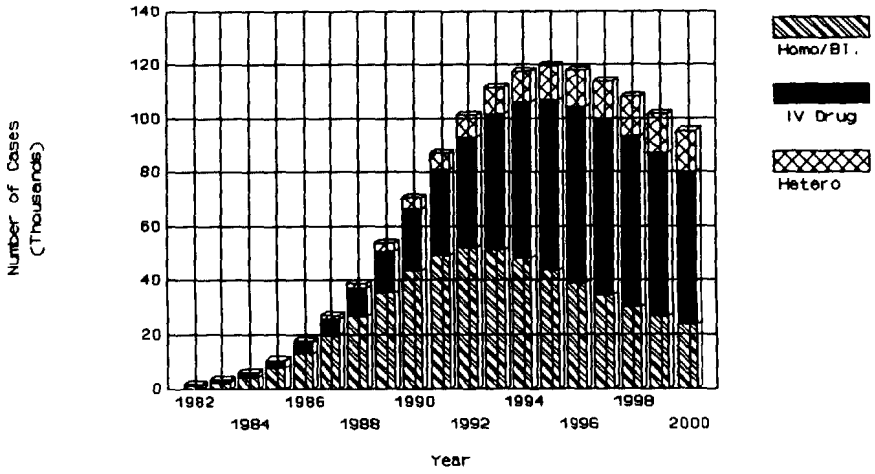


Table 18 splits the AIDS cases and deaths for 1989 and subsequent years for the middle projection between those arising from HIV infections prior to 1989 and those arising from HIV infections occurring after 1988. It illustrates the slow results of public education efforts due to the relatively long average period between HIV infection and AIDS. For example, it shows that 90 percent of the AIDS cases diagnosed in 1993 will be the result of HIV infections that already had occurred by the end of 1988.

Analysis of Behavioral Changes

The middle projection shown in Tables 16–18 assumes the various changes in sexual and IV drug frequencies shown in Table 15. Together, these changes make a significant difference in the future course of the disease, as can be seen by comparing the low and middle projections with the high projection. In order to isolate the effect of the several different types of behavior changes, the *high* projection (which assumed no behavior changes after 1988) has been modified by reducing in turn each of the different types of behavior by 50 percent. The first of these projections modifies the high projection by assuming that the frequencies of homosexual and bisexual activity are reduced by 50 percent beginning in 1989. The results are shown in Table 19.

A couple of points in Table 19 are worth noting. First, there is a small reduction in HIV infections in other than homosexuals and bisexuals. This occurs because the smaller number of infected bisexuals means that slightly fewer heterosexual women will become infected from their bisexual sex partners. Second, the percentage reduction in new HIV infections among homosexuals and bisexuals begins at 50 percent, but then climbs continuously to 67.4 percent by the year 2000. This occurs because a smaller percentage of the homosexual and bisexual populations are infected, and therefore the probability of a person encountering an infected partner is reduced. For example, by the year 2000 the proportion of homosexuals infected is only 6.8 percent, as compared with 11.3 percent in the high projection, and the proportion of bisexuals infected is only 2.3 percent, as compared with 4.5 percent in the high projection.

In Table 20 the high projection has been modified by assuming that IV drug activity reduces by 50 percent starting in 1989.

Two points in Table 20 are worth noting. First, the reduction in heterosexually transmitted HIV infections is somewhat greater than that shown in Table 19. This is the result of the reduced probability that a heterosexual will encounter an infected IV drug user as a sex partner. It illustrates the

TABLE 18

ALLOCATION OF EPIDEMIC BETWEEN PRE-1989 AND POST-1988 INFECTIONS BASED ON MIDDLE PROJECTION

Year	Pre-1989 Infections		Post-1988 Infections		Total
	Number	Percentage	Number	Percentage	
New AIDS Cases					
1989	53,826	100.0%	0	0.0	53,826
1990	70,283	99.4	441	0.6%	70,724
1991	84,933	97.6	2,122	2.4	87,055
1992	95,617	94.5	5,541	5.5	101,158
1993	100,804	90.3	10,792	9.7	111,596
1994	99,860	84.9	17,820	15.1	117,680
1995	92,674	77.4	27,075	22.6	119,749
1996	80,734	68.4	37,347	31.6	118,081
1997	68,574	60.2	45,307	39.8	113,881
1998	58,392	54.0	49,734	46.0	108,126
1999	49,738	48.8	52,091	51.2	101,829
2000	42,289	44.3	53,092	55.7	95,381
Deaths from AIDS during Year					
1989	34,098	100.0%	0	0.0	34,098
1990	46,620	99.7	132	0.3%	46,752
1991	60,028	98.7	769	1.3	60,797
1992	72,523	96.8	2,365	3.2	74,888
1993	82,461	94.0	5,249	6.0	87,710
1994	88,602	90.2	9,586	9.8	98,188
1995	90,138	85.2	15,599	14.8	105,737
1996	87,010	79.0	23,131	21.0	110,141
1997	80,671	72.3	30,943	27.7	111,614
1998	73,072	66.0	37,571	34.0	110,643
1999	65,299	60.5	42,561	39.5	107,860
2000	57,692	55.6	46,127	44.4	103,819

TABLE 18—*Continued*

Year	Pre-1989 Infections		Post-1988 Infections		Total
	Number	Percentage	Number	Percentage	
			Cumulative AIDS Cases		
1989	159,723	100.0%	0	0.0	159,723
1990	230,006	99.8	441	0.2%	230,447
1991	314,939	99.2	2,563	0.8	317,502
1992	410,556	98.1	8,104	1.9	418,660
1993	511,260	96.4	18,896	3.6	530,256
1994	611,220	94.3	36,716	5.7	647,936
1995	703,894	91.7	63,791	8.3	767,685
1996	784,628	88.6	101,138	11.4	885,766
1997	853,202	85.4	146,445	14.6	999,647
1998	911,594	82.3	196,179	17.7	1,107,773
1999	961,332	79.5	248,270	20.5	1,209,602
2000	1,003,621	76.9	301,362	23.1	1,304,983
			Cumulative AIDS Deaths		
1989	94,256	100.0%	0	0.0	94,256
1990	140,876	99.9	132	0.1%	141,008
1991	200,904	99.6	901	0.4	201,805
1992	273,427	98.8	3,266	1.2	276,693
1993	355,888	97.7	8,515	2.3	364,403
1994	444,490	96.1	18,101	3.9	462,591
1995	534,628	94.1	33,700	5.9	568,328
1996	621,638	91.6	56,831	8.4	678,469
1997	702,309	88.9	87,774	11.1	790,083
1998	775,381	86.1	125,345	13.9	900,726
1999	840,680	83.4	167,906	16.6	1,008,586
2000	898,372	80.8	214,033	19.2	1,112,405

TABLE 19

EFFECT OF 50% REDUCTION IN HOMOSEXUAL AND BISEXUAL ACTIVITY BEGINNING IN 1989 ON HIGH PROJECTION

	High Projection			50 Percent Reduction in Homosexual/Bisexual Acitivity				
				Number			Percentage Reduction	
Year	Homosexual/ Bisexual	Other	Total	Homosexual/ Bisexual	Other	Total	Homosexual/ Bisexual	Total
				New HIV Infections				
1989	30,460	158,285	188,745	15,262	158,285	173,547	49.9%	8.1%
1890	30,146	155,690	185,836	14,739	155,440	170,179	51.1	8.4
1991	29,406	142,356	171,762	13,991	141,843	155,834	52.4	9.3
1992	28,334	124,398	152,732	13,072	123,613	136,685	53.9	10.5
1993	27,062	107,313	134,375	12,056	106,251	118,307	55.5	12.0
1994	25,732	93,746	119,478	11,022	92,411	103,433	57.2	13.4
1995	24,448	83,935	108,383	10,034	82,335	92,369	59.0	14.8
2000	19,139	62,872	82,011	6,247	60,233	66,480	67.4	18.9
				New AIDS Cases				
1989	35,355	17,931	53,286	35,355	17,931	53,286	0.0	0.0
1990	43,533	27,316	70,849	43,488	27,316	70,804	0.1%	0.1%
1991	49,587	38,168	87,755	49,359	37,897	87,526	0.5	0.3
1992	52,738	50,531	103,269	52,112	50,526	102,638	1.2	0.6
1993	52,899	63,372	116,271	51,614	63,357	114,971	2.4	1.1
1994	50,465	75,790	126,255	48,631	75,354	123,985	3.6	1.8
1995	48,081	85,674	133,755	44,535	85,599	130,134	7.4	2.7
2000	36,273	99,671	135,944	26,528	99,038	125,566	26.9	7.6
				Deaths from AIDS during Year				
1989	23,301	10,797	34,098	23,301	10,797	34,098	0.0	0.0
1990	30,327	16,463	46,790	30,313	16,463	46,776	*	*
1991	37,092	23,953	61,045	37,010	23,952	60,962	0.2%	0.1%
1992	42,600	33,150	75,750	42,337	33,148	75,485	0.6	0.3
1993	46,222	43,638	89,860	45,611	43,632	89,243	1.3	0.7
1994	47,849	54,686	102,535	46,681	54,670	101,351	2.4	1.2
1995	47,929	65,471	113,400	45,945	65,435	111,380	4.1	1.8
2000	40,271	96,056	136,327	32,507	95,646	128,153	19.3	6.0

* Indicates less than 0.05%.

TABLE 20

EFFECT OF 50% REDUCTION IN IV DRUG ACTIVITY BEGINNING IN 1989 ON HIGH PROJECTION

	High Projection			50% Reduction in IV Drug Activity				
				Number			Percentage Reduction	
Year	IV Drug	Other	Total	IV Drug	Other	Total	IV Drug	Total
				New HIV Infections				
1989	126,694	62,051	188,745	67,799	62,051	129,850	46.5%	31.2%
1990	117,893	67,943	185,836	66,531	65,413	131,944	43.6	29.0
1991	98,920	72,842	171,762	63,372	68,005	131,377	35.9	23.5
1992	76,420	76,312	152,732	58,813	69,774	128,587	23.0	15.8
1993	56,135	78,240	134,375	53,445	70,757	124,202	4.8	7.6
1994	40,670	78,808	119,478	47,833	71,066	118,899	−17.6	0.5
1995	30,057	78,326	108,383	42,426	70,852	113,278	−41.2	−4.5
2000	13,795	68,216	82,011	24,016	65,414	89,430	−74.1	−9.0
				New AIDS Cases				
1989	15,628	38,198	53,826	15,628	38,198	53,826	0.0	0.0
1990	23,001	47,848	70,849	22,824	47,849	70,673	0.8%	0.2%
1991	31,957	55,798	87,755	31,096	55,791	86,887	2.7	1.0
1992	41,997	61,272	103,269	39,743	61,227	100,970	5.4	2.2
1993	52,146	64,125	116,271	47,798	63,982	111,780	8.3	3.9
1994	61,190	65,065	126,255	54,187	64,729	118,916	11.4	5.8
1995	68,237	65,518	133,755	57,990	64,871	122,861	15.0	8.1
2000	64,950	70,994	135,944	55,199	67,328	122,527	15.0	9.9
				Deaths from AIDS during Year				
1989	9,173	24,925	34,098	9,173	24,925	34,098	0.0	0.0
1990	13,917	32,873	46,790	13,864	32,873	46,737	0.4%	0.1%
1991	20,145	40,900	61,045	19,834	40,897	60,731	1.5	0.5
1992	27,714	48,036	75,750	26,573	48,201	74,774	4.1	1.3
1993	36,203	53,657	89,860	34,081	53,600	87,681	5.9	2.4
1994	44,911	57,624	102,535	41,099	57,472	98,571	8.5	3.9
1995	53,049	60,351	113,400	47,014	60,031	107,045	11.4	5.6
2000	67,478	68,849	136,327	56,042	66,245	122,287	16.9	10.3

importance of educating IV drug users to control the spread into the non-drug-using heterosexual community. (This point is further demonstrated in Table 23.)

Second, the reduction in IV drug activity initially reduces the number of new HIV infections, but after only a few years this annual reduction disappears, and by 1994 there actually is an increase in new HIV infections. This apparent anomaly occurs because under the high assumption the HIV infection has spread to more than 79 percent of the IV drug group by 1992, and so there are relatively few persons in this group left to infect. On the other hand, the reduced IV drug activity assumed in Table 20 results in only 65 percent of the group being infected in 1992.

Table 21 shows the effect on the high projection of reducing all heterosexual activity by 50 percent starting in 1989.

TABLE 21

EFFECT OF 50% REDUCTION IN HETEROSEXUAL ACTIVITY BEGINNING IN 1989 ON HIGH PROJECTION

	High Projection			50% Reduction in Heterosexual Activity				
				Number			Percentage Reduction	
Year	Heterosexual	Other	Total	Heterosexual	Other	Total	Heterosexual	Total
New HIV Infections								
1989	31,591	157,154	188,745	15,798	157,154	172,952	50.0%	8.4%
1990	37,797	148,039	185,836	18,542	148,039	166,581	50.9	10.4
1991	43,436	128,326	171,762	20,924	128,325	149,249	51.8	13.1
1992	47,978	104,754	152,732	22,683	104,755	127,438	52.7	16.6
1993	51,178	83,197	134,375	23,715	83,197	106,912	53.7	20.4
1994	53,077	66,401	119,478	24,058	66,402	90,460	54.7	24.3
1995	53,878	54,505	108,383	23,838	54,505	78,343	55.8	27.7
2000	49,077	32,934	82,011	18,817	32,935	51,752	61.7	36.9
New AIDS Cases								
1989	2,842	50,984	53,826	2,842	50,984	53,826	0.0	0.0
1990	4,315	66,534	70,849	4,268	66,534	70,802	1.1%	0.1%
1991	6,211	81,544	87,755	5,964	81,544	87,508	4.0	0.3
1992	8,534	94,735	103,269	7,825	94,735	102,560	8.3	0.7
1993	11,226	105,045	116,271	9,700	105,045	114,745	13.6	1.3
1994	14,200	112,055	126,255	11,422	112,055	123,477	19.6	2.2
1995	17,437	116,318	133,755	12,843	116,318	129,161	26.3	3.4
2000	34,721	101,223	135,944	18,156	101,223	119,379	47.7	12.2
Deaths from AIDS during Year								
1989	1,624	32,474	34,098	1,624	32,474	34,098	0.0	0.0
1990	2,546	44,244	46,790	2,532	44,243	46,775	0.5%	0.0%
1991	3,807	57,238	61,045	3,719	57,237	60,956	2.3	0.1
1992	5,436	70,314	75,750	5,142	70,314	75,456	5.4	0.4
1993	7,435	82,425	89,860	6,724	82,425	89,149	9.6	0.8
1994	9,774	92,761	102,535	8,357	92,760	101,117	14.5	1.4
1995	12,422	100,978	113,400	9,918	100,978	110,896	20.2	2.2
2000	28,578	107,749	136,327	16,171	107,748	123,919	43.4	9.1

Note that the overall effect of reducing heterosexual activity by 50 percent as compared with the high projection is greater than the comparable reduction in homosexual and bisexual activity shown in Table 19. This is because under the high projection the number of new HIV infections for heterosexuals exceeds that for homosexuals and bisexuals after 1988. Homosexuals and bisexuals have already made major changes in their sexual practices, whereas

heterosexuals have made much less drastic changes, because of the much lower risk levels. This point is further discussed later in the paper.

Table 22 shows the effect on the high projection of a 50 percent reduction in heterosexual activity with bisexuals and IV drug users, but otherwise no reduction in heterosexual activity.

TABLE 22

EFFECT OF 50% REDUCTION IN HETEROSEXUAL ACTIVITY WITH BISEXUALS AND IV DRUG USERS BEGINNING IN 1989 ON HIGH PROJECTION

	High Projection			50% Reduction with Bisexual and IV Drug Users				
				Number			Percentage Reduction	
Year	Heterosexual	Other	Total	Heterosexual	Other	Total	Heterosexual	Total
New HIV Infections								
1989	31,591	157,154	188,745	18,143	157,154	175,297	42.6%	7.1%
1990	37,797	148,039	185,836	21,350	148,038	169,388	43.5	8.9
1991	43,436	128,326	171,762	24,243	128,325	152,568	44.2	11.2
1992	47,978	104,754	152,732	26,547	104,754	131,301	44.7	14.0
1993	51,178	83,197	134,375	28,137	83,197	111,334	45.0	17.1
1994	53,077	66,401	119,478	29,034	66,401	95,435	45.3	20.1
1995	53,878	54,505	108,383	29,348	54,505	83,853	45.5	22.6
2000	49,077	32,934	82,011	26,427	32,935	59,362	46.2	27.6
New AIDS Cases								
1989	2,842	50,984	53,826	2,842	50,984	53,826	0.0	0.0
1990	4,315	66,534	70,849	4,275	66,534	70,809	0.9%	0.1%
1991	6,211	81,544	87,755	6,000	81,544	87,544	3.4	0.2
1992	8,534	94,735	103,269	7,929	94,736	102,665	7.1	0.6
1993	11,226	105,045	116,271	9,926	105,044	114,970	11.6	1.1
1994	14,200	112,055	126,255	11,834	112,055	123,889	16.7	1.9
1995	17,437	116,318	133,755	13,530	116,318	129,848	22.4	2.9
2000	34,721	101,223	135,994	20,927	101,224	122,151	39.7	10.1
Deaths from AIDS during Year								
1989	1,624	32,474	34,098	1,624	32,474	34,098	0.0	0.0
1990	2,546	44,244	46,790	2,534	44,243	46,777	0.5%	*
1991	3,807	57,238	61,045	3,732	57,237	60,969	2.0	0.1%
1992	5,436	70,314	75,750	5,186	70,314	75,500	4.6	0.3
1993	7,435	82,425	89,860	6,829	82,425	89,254	8.2	0.7
1994	9,774	92,761	102,535	8,567	92,760	101,327	12.3	1.2
1995	12,422	100,978	113,400	10,291	100,978	111,269	17.2	1.9
2000	28,578	107,749	136,327	18,183	107,749	125,932	36.4	7.6

* Indicates less than 0.05%.

A comparison of Table 22 with Table 21 shows that a very large part of the reductions in new HIV infections that would result from a general decrease in heterosexual activity would be achieved by merely avoiding sexual

activity with those in the high-risk groups, but otherwise not making any changes in sexual practices.

This point is further illustrated by Table 23, which compares the number of new heterosexual infections that are assumed to occur under the *middle* projection with those that would occur if there were no sexual contact between heterosexuals and IV drug users, and between heterosexuals and either IV drug users or bisexuals, beginning in 1989. As the table shows, in the latter case about 80 percent of new HIV infections among heterosexuals would not occur.

TABLE 23

EFFECT ON HETEROSEXUALS OF NO SEXUAL CONTACT WITH BISEXUALS AND IV DRUG USERS AFTER 1988

Year	Middle Projection	No Sexual Contact with IV Drug Users		No Sexual Contact with IV Drug Users or Bisexuals	
		Number	Ratio	Number	Ratio
New Heterosexual HIV Infections					
1989	22,120	9,207	42%	4,037	18%
1990	16,904	8,814	52	4,020	24
1991	17,122	8,327	49	3,828	22
1992	16,719	7,694	46	3,564	21
1993	16,870	7,435	44	3,456	20
1994	16,782	7,098	42	3,295	20
1995	16,490	6,714	41	3,093	19
2000	13,666	4,882	36	2,124	16
New Heterosexual AIDS Cases					
1989	2,842	2,842	100%	2,842	100%
1990	4,287	4,248	99	4,233	99
1991	6,035	5,855	97	5,779	96
1992	7,958	7,498	94	7,293	92
1993	9,866	8,968	91	8,554	87
1994	11,553	10,039	87	9,333	81
1995	12,862	10,495	82	9,394	73
2000	15,139	8,900	59	6,204	41
Heterosexual Deaths from AIDS during Year					
1989	1,624	1,624	100%	1,624	100%
1990	2,538	2,526	100	2,521	99
1991	3,746	3,680	98	3,653	98
1992	5,206	5,009	96	4,922	95
1993	6,826	6,389	94	6,191	91
1994	8,472	7,665	90	7,292	86
1995	10,001	8,660	87	8,037	80
2000	14,274	9,314	65	7,104	50

Long-Range Projections of the AIDS Epidemic

Although most of the projections in this paper go only to the year 2000, the model is capable of projecting the epidemic to 2030. Obviously, any such projection is highly speculative with regard to actual results; however, such projections are helpful in determining the extent to which the epidemic will affect the various risk groups under "steady state" assumptions. They also may be of value in calculating additional reserves needed to allow for excess AIDS mortality and morbidity under life and health insurance contracts.

Table 24 shows the results through the year 2030 split by race, assuming a continuation of the middle-projection assumptions. The table indicates that, in terms of new HIV infections, the epidemic eventually will stabilize at slightly fewer than 25,000 cases per year, with future increases coming from population growth. This number is far lower than the number of new HIV infections that were occurring a couple of years ago or the number of AIDS cases that will be occurring a few years from now. For homosexuals and bisexuals this appears to be primarily the result of further educational efforts; however, for IV drug users the largest factor is the decrease in the number of persons in this group, caused by the large number of AIDS deaths. Table 25 illustrates this by comparing the initial assumed percentages of persons in the high-risk groups with the percentages calculated by the model for later years.

Table 24 also indicates that within a few years there will be substantially more AIDS cases among nonwhites than among whites, even though the reverse has been true up until now. This is because of the higher incidence of IV drug use among nonwhites combined with the shift in the incidence of AIDS from homosexuals and bisexuals to IV drug users.

Table 26 further analyzes the results of extending the middle projection to the year 2030 by showing the proportion of the population in each of the racial and risk groups that is HIV+. Under the assumptions used in the middle projection, the proportion of homosexuals and bisexuals that are infected is at a high at present. In the future, the number of deaths from AIDS among these risk groups will exceed the number of new HIV infections, so the proportion infected will gradually decline.

For IV drug users, however, the prognosis is far more pessimistic. For them, the proportion infected will continue to increase until the turn of the century, at which point it will be more than 80 percent. Only then will it level off.

TABLE 24

LONG-RANGE PROJECTIONS OF AIDS EPIDEMIC BASED ON MIDDLE-PROJECTION ASSUMPTION

Year	White	Black	Other	Total
		New HIV Infections		
1988	59,131	76,257	42,537	177,925
1989	42,072	67,755	37,133	146,960
1990	34,416	55,093	30,130	119,639
1995	17,405	25,492	14,072	56,969
2000	11,337	16,631	9,214	37,182
2005	8,517	12,800	7,094	28,411
2010	7,687	11,563	6,412	25,662
2015	7,407	11,154	6,187	24,748
2020	7,316	10,955	6,081	24,352
2025	7,340	10,909	6,061	24,310
2030	7,432	10,973	6,103	24,508
		New AIDS Cases		
1988	23,363	9,508	6,095	38,966
1989	31,502	13,638	8,686	53,826
1990	40,071	18,811	11,842	70,724
1995	52,410	42,548	24,789	119,747
2000	35,947	37,943	21,489	95,379
2005	17,503	24,987	13,824	56,314
2010	10,311	15,234	8,430	33,975
2015	7,862	11,741	6,507	26,110
2020	6,920	10,407	5,771	23,098
2025	6,612	9,935	5,511	22,058
2030	6,531	9,764	5,421	21,716
		Deaths from AIDS during Year		
1988	14,372	5,727	3,665	23,764
1989	20,276	8,435	5,386	34,097
1990	27,136	12,005	7,610	46,751
1995	49,917	35,039	20,779	105,735
2000	41,459	39,672	22,686	103,817
2005	23,764	29,670	16,576	70,010
2010	12,856	18,491	10,239	41,586
2015	8,757	13,033	7,218	29,008
2020	7,256	10,885	6,034	24,175
2025	6,723	10,105	5,605	22,433
2030	6,559	9,825	5,453	21,837

TABLE 25

PERCENTAGES OF POPULATION IN HIGH-RISK GROUPS

Race and Risk Group	1981	1988	1995	2000	2010	2020	2030
Homosexual Male							
White	2.67%	2.6%	2.5%	2.3%	2.3%	2.3%	2.3%
Black	4.11	4.1	4.0	3.9	3.9	3.9	3.9
Other	4.15	4.1	3.9	3.8	3.7	3.8	3.8
Bisexual Male							
White	1.65	1.6	1.6	1.6	1.6	1.6	1.6
Black	6.55	6.5	6.5	6.5	6.6	6.6	6.6
Other	3.96	4.0	3.9	3.9	3.9	3.9	3.9
Male IV Drug User							
White	0.23	0.2	0.2	0.2	0.1	0.1	0.1
Black	3.96	3.9	3.4	2.5	1.3	1.0	1.0
Other	3.22	3.2	3.8	2.0	1.0	0.8	0.8
Female IV Drug User							
White	0.06	0.1	*	*	*	*	*
Black	1.27	1.3	1.1	0.8	0.4	0.3	0.3
Other	0.52	0.5	0.4	0.3	0.2	0.1	0.1

* Indicates less than 0.05%.

For heterosexuals other than IV drug users, the AIDS epidemic will never reach anything near the proportions that it already has reached for the high-risk groups. The proportion of nonwhite heterosexuals that will be infected will peak at about 0.4 percent around the turn of the century before beginning to decline. For whites, the proportion will remain below 0.05 percent.

Tables 24–26 are based on extending the middle projection beyond the year 2000 by using the same assumptions of sexual and IV drug behavior as used from 1992 to 2000. As discussed earlier, these assumptions involve considerable reduction in sexual and IV drug activity from that of a few years ago and some reduction from the current levels as determined in the validation process. To determine the effect of higher levels of such activity, projections were done through the year 2030 based on two higher levels of sexual and IV drug activity:

1. Extension of the high projection, that is, no further reductions in sexual and IV drug activity beyond the levels developed in the validation process for 1988.
2. Resumption beginning in 1989 of the levels of sexual and IV drug activity that were the case in 1982.

The results of these projections are shown in Table 27.

Although the high projection could turn out to be realistic if further AIDS education efforts are unsuccessful, the projection assuming a return to 1982

TABLE 26

PROPORTION OF RISK GROUPS WITH HIV INFECTION BASED ON MIDDLE PROJECTION

Year	Race			Race		
	White	Black	Other	White	Black	Other
	Homosexual			Bisexual		
1982	2.4%	2.0%	2.2%	0.5%	0.7%	0.7%
1983	4.4	3.4	4.0	1.3	1.3	1.4
1984	7.5	5.4	6.6	2.4	2.3	2.3
1985	11.3	7.8	9.7	3.4	2.6	3.1
1986	14.9	9.8	12.6	4.5	3.1	3.9
1987	17.2	11.0	14.4	5.4	3.6	4.6
1988	18.5	11.6	15.3	6.0	3.9	5.0
1989	18.7	11.6	15.4	6.3	3.9	5.2
1990	18.3	11.2	15.0	6.2	3.8	5.1
1991	17.6	10.7	14.3	6.1	3.7	4.9
1992	16.6	10.0	13.5	5.8	3.5	4.7
1993	15.6	9.3	12.6	5.5	3.2	4.4
1994	14.4	8.4	11.5	5.1	3.0	4.1
1995	13.1	7.6	10.5	4.7	2.7	3.7
2000	7.5	4.1	5.8	2.8	1.5	2.2
2005	4.2	2.3	3.3	1.6	0.9	1.3
2010	3.2	1.7	2.4	1.2	0.6	0.9
2015	2.8	1.5	2.2	1.0	0.6	0.8
2020	2.6	1.4	2.0	1.0	0.5	0.8
2025	2.5	1.4	1.9	0.9	0.5	0.7
2030	2.4	1.3	1.9	0.9	0.5	0.7
	IV Drug User			Heterosexual		
1982	2.3%	2.0%	2.1%	*	*	*
1983	4.7	3.6	3.6	*	*	*
1984	8.1	6.3	6.3	*	*	*
1985	13.5	10.6	10.7	*	*	*
1986	21.3	17.3	17.5	*	0.1%	*
1987	31.5	26.5	26.7	*	0.1	0.1%
1988	42.8	37.3	37.5	*	0.2	0.1
1989	53.8	48.4	48.7	*	0.2	0.2
1990	62.9	58.3	58.6	*	0.3	0.2
1991	69.8	66.0	66.3	*	0.3	0.2
1992	74.2	71.4	71.6	*	0.3	0.2
1993	76.9	74.7	74.9	*	0.3	0.2
1994	79.1	77.4	77.6	*	0.3	0.2
1995	80.6	79.5	79.7	*	0.4	0.3
2000	83.2	83.8	83.9	*	0.4	0.3
2005	83.0	82.4	82.4	*	0.3	0.2
2010	79.7	79.9	79.8	*	0.3	0.2
2015	79.3	79.4	79.4	*	0.3	0.2
2020	80.0	80.0	80.0	*	0.2	0.2
2025	80.7	80.7	80.7	*	0.2	0.2
2030	81.3	81.3	81.3	*	0.2	0.2

* Indicates less than 0.05%.

TABLE 27

LONG-RANGE PROJECTIONS OF AIDS EPIDEMIC

Year	Middle	High	1982 Levels
		New HIV Infections	
1988	177,925	177,925	177,925
1989	146,960	188,740	640,070
1990	119,639	185,830	823,601
1995	56,969	108,378	578,972
2000	37,182	82,010	360,024
2005	28,411	70,671	311,105
2010	25,662	66,564	288,034
2015	24,748	65,771	281,512
2020	24,352	66,671	283,651
2025	24,310	68,854	291,825
2030	24,508	71,826	304,273
		New AIDS Cases	
1988	38,966	38,966	38,966
1989	53,826	53,826	53,826
1990	70,724	70,849	72,203
1995	119,747	133,753	276,402
2000	95,379	135,940	537,107
2005	56,314	100,456	468,251
2010	33,975	74,904	352,215
2015	26,110	63,725	279,526
2020	23,098	59,776	258,504
2025	22,058	58,955	252,407
2030	21,716	59,847	254,573
		Deaths from AIDS during Year	
1988	23,764	23,764	23,764
1989	34,097	34,097	34,097
1990	46,751	46,790	47,195
1995	105,735	113,399	191,469
2000	103,817	136,323	461,276
2005	70,010	112,655	490,791
2010	41,586	83,992	396,430
2015	29,008	77,683	303,619
2020	24,175	61,182	266,266
2025	22,433	59,221	254,488
2030	21,837	59,492	253,642

levels of sexual and IV drug activity would appear to be unrealistic if not impossible, because it assumes that little or no precautions are taken even by those in the high-risk groups, even though the proportion of persons infected in those groups would approach 100 percent within a few years, and even though there is good evidence that major changes already have

taken place since 1982 in homosexual and bisexual practices because of the AIDS epidemic.

The purpose of showing the "high" and "1982 levels" columns in Table 27 is not to present alternative long-range projections of the AIDS epidemic, but rather to illustrate that, even under extremely adverse assumptions, the AIDS epidemic will level off and will not generally devastate the population, except for those in the high-risk groups.

VI. DISCUSSION OF DATA AND ASSUMPTIONS USED IN PROJECTIONS

Section IV discussed the data and assumptions used in the validation process. This section further comments on several of those assumptions and discusses the assumptions used in the projections. In addition, it explores the effect on the projections of varying certain of the assumptions.

Rate of Progression from HIV+ to AIDS

In Table 1, two sets of progression rates from HIV+ to AIDS were shown. The projections already discussed have been based on the SFCC/CDC rates because they are believed to be more representative of the progression from HIV+ to AIDS in the U.S. and because they give a current level of HIV infections that is more consistent with other estimates. However, it is useful to compare the results from the two scales on the projections of the epidemic. Table 28 compares the results of the middle projection with a projection made by using the Frankfurt scale of progression rates in the validation process. In doing the validation process based on the Frankfurt scale, the number of initial HIV infections in 1981 was adjusted to produce the same number of cumulative AIDS cases through 1988 as under the middle projection. No adjustments were made in the assumed frequencies of sexual or IV drug behavior.

Table 28 clearly shows how sensitive the projections of the epidemic are to the scale of progression rates, for a given number of AIDS cases. The more rapid Frankfurt scale of progression rates results in a 24.7 percent decrease in the cumulative number of AIDS cases by the year 2000, even though the number of such cases through 1988 was set to be the same. However, beginning in 1993 the number of new HIV infections with the Frankfurt scale is greater than that with the SFCC/CDC scale, indicating that the very-long-term progress of the epidemic may not be as dependent on the scale of progression rates as is suggested by the results over the next few years.

TABLE 28

COMPARISON OF SAN FRANCISCO CITY CLINIC/CDC AND FRANKFURT PROGRESSION RATES BASED ON MIDDLE-PROJECTION BEHAVIORAL ASSUMPTIONS

Year	SFCC/CDC	Frankfurt	Percentage Increase: Frankfurt to SFCC/CDC
		New HIV Infections	
1988	177,929	121,880	−31.5%
1989	146,965	115,163	−21.6
1990	119,642	104,808	−12.4
1991	94,955	89,342	−5.9
1992	74,098	71,537	−3.5
1993	68,401	68,771	0.5
1994	62,568	65,235	4.3
1995	56,971	61,347	7.7
2000	37,184	42,899	15.4
		New AIDS Cases	
1988	38,967	37,239	−4.4%
1989	53,286	47,266	−11.3
1990	70,724	56,565	−20.0
1991	87,055	64,751	−25.6
1992	101,158	71,237	−29.6
1993	111,596	75,601	−32.3
1994	117,680	77,691	−34.0
1995	119,749	77,711	−35.1
2000	95,381	70,607	−26.0
		Deaths from AIDS during Year	
1988	23,764	23,243	−2.2%
1989	34,098	31,633	−7.2
1990	46,752	40,311	−13.8
1991	60,979	48,774	−20.0
1992	74,888	56,553	−24.5
1993	87,710	63,191	−28.0
1994	98,188	68,311	−30.4
1995	105,737	71,700	−32.2
2000	103,819	73,170	−29.5
		HIV+ Persons at End of Year	
1988	1,183,317	658,786	−44.3%
1989	1,296,184	742,316	−42.7
1990	1,396,075	806,812	−41.1
1991	1,403,233	847,380	−39.6
1992	1,402,443	862,364	−38.5
1993	1,383,134	867,945	−37.2
1994	1,347,514	864,869	−35.8
1995	1,298,748	854,516	−34.2
2000	974,461	733,943	−24.7

Also, the Frankfurt scale results in less than 700,000 HIV infections at the end of 1988, whereas the SFCC/CDC scale results in nearly 1.2 million. The current CDC estimate of the number of HIV infections is between 1.0 and 1.5 million.

Undercounting of AIDS Cases

As mentioned earlier, there is some evidence of undercounting of AIDS cases reported to the CDC. This can come in three forms. First, there can be significant delays in the reporting of some cases. Second, certain types of cases were not considered to be an AIDS-related illness prior to September 1987, at which time the CDC changed its definition of AIDS to include them. Finally, some cases for various reasons never are reported to the CDC as AIDS cases, but in fact should be included when tracking the course of the epidemic.

These reporting problems have very different effects on the projections:

1. The late reporting of cases already has been allowed for in the development of the aging factors used in calculating the number of AIDS cases by date of diagnosis shown in Table 7. Therefore, assuming that the aging factors have been correctly developed, no further consideration should be necessary.
2. AIDS cases not reported prior to September 1987 but now being reported under the new definition create a distortion in the validation process. However, they may actually result in overestimating the future course of the epidemic, rather than underestimating it, because they would cause the validation process to understate the numbers of cases for 1987 and prior, but not for 1988. This in turn would artificially increase the upward slope of the curve of AIDS cases over what it would have been if the current AIDS definition had been in effect from the start, and the validation process would in turn produce a higher average number of sexual and IV drug acts than is actually the case.
3. AIDS cases that never get reported do of course result in an understatement of the epidemic. However, the effect is not as obvious as one might think.

The actual amount of AIDS cases that never get counted is of course impossible to determine with any degree of precision. The CDC has estimated that it eventually captures 84 percent of all AIDS cases in its system, for an undercounting rate of 19 percent of those reported. Others have estimated that the problem is somewhat larger—perhaps as high as 50 percent.

It is beyond the scope of this paper to further analyze the reasons for the late reporting or undercounting of AIDS cases. However, it is instructive to study the effect of such undercounting on the projections of the epidemic. Table 29 shows the effect on the middle projection of increasing the number

of 1981 HIV infections by 20 percent and 50 percent. Several points in Table 29 should be noted:

1. Increasing the number of 1981 HIV infections by 20 percent and 50 percent increases the cumulative totals of AIDS cases through 1988 by 18.7 percent and 46 percent, respectively. Therefore, the 20 percent increase in 1981 HIV infections should be representative of the CDC's estimated 19 percent undercounting, and the 50 percent increase in 1981 infections represents the effect of 46 percent undercounting.
2. If there had been 19 percent undercounting to date, future projections of AIDS cases cannot merely be increased by 19 percent to allow for the undercounting. Cumulative AIDS cases through 1991 actually should be increased by only 16.9 percent, and cumulative AIDS cases through the year 2000 should be increased by only 10.9 percent. Similarly, undercounting of 46 percent through 1988 results in only 41 percent undercounting through 1991 and 26 percent through the year 2000.
3. Even more dramatic is the effect of the undercounting on the number of new HIV infections. If in fact there is undercounting, beginning in 1990 the number of new HIV infections will actually be lower than would have otherwise been the case, because the epidemic actually will have run its course faster within the IV drug group than would have been the case under the middle projection. The resulting quicker saturation of this group reduces the number of new infections by more than the total increase for the other groups.

Variations in the Size of High-Risk Groups

The basic projections have been made by using estimates of the number of persons in the high-risk groups. Because these are only rough estimates of the number of persons in these groups, it is instructive to examine the effect of a significant error in these estimates on the future of the epidemic.

For the homosexual and bisexual population, a projection was made by using the middle-projection assumptions, except the percentages of the population in the homosexual and bisexual populations were increased 50 percent. As shown in Table 30, even though the homosexual/bisexual population is increased by 50 percent, the percentage increase in the number of new HIV infections and new AIDS cases is far less. This is because the effect of the saturation of these risk groups is relatively small.

The effect on the middle projection of increasing the IV drug population by 50 percent is very different, as shown in Table 31. Although the percentage increase in number of new HIV infections and new AIDS cases currently is less than 50 percent, by 1990 the percentage increase in new HIV infections actually exceeds 50 percent and continues to grow until it exceeds 90 percent by 1995. This occurs because under the middle projection

TABLE 29

EFFECT OF UNDERCOUNTING OF AIDS CASES

Year	Middle Projection	20% Undercounting		50% Undercounting	
		Number	Percentage Increase	Number	Percentage Increase
		New HIV Infections			
1982	82,775	98,777	19.3%	122,440	47.9%
1983	127,178	150,706	18.5	184,865	45.4
1984	167,368	196,244	17.3	236,995	41.6
1985	197,708	228,604	15.6	270,537	36.8
1986	200,812	227,647	13.4	262,023	30.5
1987	197,556	217,912	10.3	241,777	22.4
1988	177,929	188,974	6.2	199,825	12.3
1989	146,965	149,627	1.8	150,301	2.3
1990	119,642	118,264	−1.2	115,181	−3.7
1991	94,955	92,541	−2.5	89,215	−6.0
1992	74,098	72,177	−2.6	70,012	−5.5
1993	68,401	66,278	−3.1	64,165	−6.2
1994	62,568	60,472	−3.3	58,585	−6.4
1995	56,971	55,052	−3.4	53,479	−6.1
2000	37,184	36,504	−1.8	36,277	−2.4
		New AIDS Cases			
1982	1,724	2,069	20.0%	2,586	50.0%
1983	3,372	4,045	20.0	5,053	49.9
1984	6,130	7,343	19.8	9,156	49.4
1985	10,697	12,786	19.5	15,888	48.5
1986	17,798	21,203	19.1	26,223	47.3
1987	27,209	32,272	18.6	39,658	45.8
1988	38,967	45,954	17.9	56,021	43.8
1989	53,826	63,063	17.2	76,187	41.5
1990	70,724	82,238	16.3	98,358	39.1
1991	87,055	100,322	15.2	118,593	36.2
1992	101,158	115,379	14.1	134,613	33.1
1993	111,596	125,823	12.7	144,704	29.7
1994	117,680	131,028	11.3	148,405	26.1
1995	119,749	131,627	9.9	146,841	22.6
2000	95,381	99,776	4.6	105,532	10.6

TABLE 29—*Continued*

Year	Middle Projection	20% Undercounting		50% Undercounting	
		Number	Percentage Increase	Number	Percentage Increase
		Deaths from AIDS during Year			
1982	517	621	20.1%	776	50.1%
1983	1,529	1,834	19.9	2,292	49.9
1984	3,109	3,727	19.9	4,651	49.6
1985	5,675	6,790	19.6	8,452	48.9
1986	9,790	11,685	19.4	14,490	48.0
1987	15,773	18,759	18.9	23,144	46.7
1988	23,764	28,134	18.4	34,487	45.1
1989	34,098	40,147	17.7	48,836	43.2
1990	46,752	54,697	17.0	65,967	41.1
1991	60,979	70,612	15.8	84,345	38.3
1992	74,888	86,256	15.2	101,933	36.1
1993	87,710	100,090	14.1	116,905	33.3
1994	98,188	110,918	13.0	127,945	30.3
1995	105,737	118,180	11.8	134,588	27.3
2000	103,819	110,614	6.5	119,390	15.0
		Cumulative AIDS Cases			
1982	1,724	2,069	20.0%	2,586	50.0%
1983	5,096	6,114	20.0	7,639	49.9
1984	11,226	13,457	19.9	16,796	49.6
1985	21,923	26,243	19.7	32,684	49.1
1986	39,721	47,446	19.4	58,906	48.3
1987	66,931	79,718	19.1	98,565	47.3
1988	105,897	125,672	18.7	154,585	46.0
1989	159,723	188,735	18.2	230,772	44.5
1990	230,447	270,973	17.6	329,131	42.8
1991	317,502	371,295	16.9	447,724	41.0
1992	418,661	486,674	16.2	582,337	39.1
1993	530,256	612,498	15.5	727,041	37.1
1994	647,936	743,526	14.8	875,447	35.1
1995	767,685	875,153	14.0	1,022,288	33.2
2000	1,304,982	1,447,563	10.9	1,639,424	25.6

TABLE 29—*Continued*

Year	Middle Projection	20% Undercounting		50% Undercounting	
		Number	Percentage Increase	Number	Percentage Increase
		Cumulative Deaths from AIDS			
1982	517	621	20.1%	776	50.1%
1983	2,046	2,455	20.0	3,068	50.0
1984	5,155	6,182	19.9	7,718	49.7
1985	10,830	12,972	19.8	16,171	49.3
1986	20,620	24,657	19.6	30,660	48.7
1987	36,394	43,416	19.3	53,805	47.8
1988	60,158	71,550	18.9	88,292	46.8
1989	94,256	111,697	18.5	137,128	45.5
1990	141,008	166,394	18.0	203,096	44.0
1991	201,805	237,005	17.4	287,441	42.4
1992	276,694	323,261	16.8	389,374	40.7
1993	364,404	423,352	16.2	506,279	38.9
1994	462,592	534,270	15.5	634,225	37.1
1995	568,328	652,450	14.8	768,813	35.3
2000	1,112,406	1,242,762	11.7	1,418,891	27.6

TABLE 30

EFFECT OF VARIATIONS IN SIZE OF TOTAL HOMOSEXUAL AND BISEXUAL POPULATION BASED ON MIDDLE-PROJECTION ASSUMPTIONS

Year	Middle Projection		50% Larger Homosexual/Bisexual Population			
			Number		Percentage Change	
	Homosexual/ Bisexual	Total	Homosexual/ Bisexual	Total	Homosexual/ Bisexual	Total
New HIV Infections						
1988	30,355	177,929	33,201	181,068	9.4%	1.8%
1989	13,525	146,965	14,793	148,471	9.4	1.0
1990	11,293	119,642	12,327	120,853	9.2	1.0
1991	8,966	94,955	9,766	95,921	8.9	1.0
1992	8,266	74,098	9,012	74,993	9.0	1.2
1993	7,507	68,401	8,189	69,220	9.1	1.2
1994	6,746	62,568	7,359	63,303	9.1	1.2
1995	6,025	56,971	6,570	57,622	9.0	1.1
2000	3,371	37,184	3,662	37,509	8.6	0.9
New AIDS Cases						
1988	27,023	38,967	27,686	39,643	2.5%	1.7%
1989	35,355	53,826	36,440	54,934	3.1	2.1
1990	43,483	70,724	45,068	72,348	3.6	2.3
1991	49,328	87,055	51,424	89,209	4.2	2.5
1992	52,010	101,158	54,519	103,745	4.8	2.6
1993	51,375	111,596	54,101	114,421	5.3	2.5
1994	48,173	117,680	50,902	120,527	5.7	2.4
1995	43,763	119,749	46,336	122,454	5.9	2.3
2000	23,880	95,381	25,423	97,059	6.5	1.8
Deaths from AIDS during Year						
1988	16,942	23,764	17,275	24,104	2.0%	1.4%
1989	23,301	34,098	23,892	34,702	2.5	1.8
1990	30,312	46,752	31,247	47,709	3.1	2.0
1991	36,999	60,979	38,388	62,171	3.6	2.0
1992	42,296	74,888	44,045	76,687	4.1	2.4
1993	45,504	87,710	47,597	89,870	4.6	2.5
1994	46,455	98,188	48,771	100,589	5.0	2.4
1995	45,531	105,737	47,936	108,242	5.3	2.4
2000	30,460	103,819	32,327	105,821	6.1	1.9

the IV drug group has already become heavily saturated with HIV + persons (49 percent of IV drug users are assumed to be already infected by 1989), so the number of new infections is reduced. On the other hand, only 38 percent would already be infected by 1989 if the total IV drug population were 50 percent larger. By the year 2000, the 49 percent saturation would have increased to 84 percent under the middle projection, for an increase of 35 percent. On the other hand, the 38 percent saturation would climb to 81 percent by the year 2000 under the projection by using a population of 50 percent more IV drug users, for an increase of 43 percent.

Examining the effect of reducing the assumed IV drug population by one-third is useful for two reasons: First, the total IV drug population may be overstated, at least in terms of those who share needles and therefore are a factor in spreading the epidemic. Second, the model is unable to allow directly for the effect on the epidemic within the IV drug population of variations by region in the proportions infected. Reducing the total IV drug population is an approximate way to do this.

Table 32 shows that a one-third reduction in the assumed total IV drug population results in a reduction in the number of new HIV infections of more than one-third. The reason for this is analogous to that discussed for Table 31.

Finally, what is the effect of reducing the heterosexual population to allow for the fact that many older people are no longer sexually active and should be removed from the population of heterosexuals who are susceptible to HIV infection? Table 33 shows the effect of reducing the assumed population of heterosexuals by one-third without changing the number of persons in the high-risk groups. Reducing the assumed heterosexual population by one-third has virtually no effect on the projection of the epidemic. This is because only a very small percentage of the heterosexual population will be infected, so there is no "saturation effect." As a result, changing the size of the total population does not measurably reduce the magnitude of the epidemic in the future. (In fact, some years show a very small increase, partly because of rounding, but also because the bisexual and IV drug populations are assumed to remain the same size, so the risk that a heterosexual will encounter a high-risk person increases by slightly more than 50 percent when the heterosexual population is decreased by one-third.)

Variations in Rate of Population Growth

Somewhat related to variations in the size of the various risk groups are variations in the assumed growth rate of the population as a whole.

TABLE 31

EFFECT OF VARIATIONS IN SIZE OF TOTAL IV-DRUG-USING POPULATION BASED ON MIDDLE-PROJECTION ASSUMPTIONS

Year	Middle Projection		50% Larger IV-Drug-Using Population			
			Number		Percentage Change	
	IV Drug	Total	IV Drug	Total	IV Drug	Total
New HIV Infections						
1988	122,084	177,929	161,965	219,800	32.7%	23.5%
1989	111,320	146,965	161,378	199,799	45.0	36.0
1990	91,445	119,642	144,658	174,879	58.2	46.2
1991	68,867	94,955	116,525	145,227	69.2	52.9
1992	49,113	74,098	87,160	115,195	77.5	55.5
1993	44,024	68,401	81,031	108,913	84.1	59.2
1994	39,040	62,568	73,946	101,390	89.4	62.0
1995	34,456	56,971	66,578	93,356	93.2	63.9
2000	20,147	37,184	38,339	60,279	90.3	62.1
New AIDS Cases						
1988	10,159	38,967	10,673	39,491	5.1%	1.3%
1989	15,628	53,826	16,823	55,055	7.6	2.3
1990	22,955	70,724	25,401	73,255	10.7	3.6
1991	31,693	87,055	36,155	91,688	14.1	5.3
1992	41,190	101,158	48,537	108,803	17.8	7.6
1993	50,354	111,596	61,386	123,099	21.9	10.3
1994	57,955	117,680	73,207	133,623	26.3	13.5
1995	63,123	119,749	82,687	140,253	31.0	17.1
2000	56,363	95,381	86,128	127,492	52.8	33.7
Deaths from AIDS during Year						
1988	5,828	23,764	6,051	23,991	3.8%	1.0%
1989	9,173	34,098	9,720	34,659	6.0	1.6
1990	13,903	46,752	15,090	47,976	8.5	2.6
1991	20,052	60,979	22,353	63,180	11.5	3.6
1992	27,386	74,888	31,415	79,074	14.7	5.6
1993	35,381	87,710	41,823	94,417	18.2	7.6
1994	43,261	98,188	52,754	108,091	21.9	10.1
1995	50,204	105,737	63,195	119,321	25.9	12.8
2000	59,086	103,819	85,834	132,387	45.3	27.5

TABLE 32

EFFECT OF VARIATIONS IN SIZE OF TOTAL IV-DRUG-USING POPULATION BASED ON MIDDLE-PROJECTION ASSUMPTIONS

Year	Middle Projection		33-1/3% Smaller IV-Drug-Using Population			
			Number		Percentage Change	
	IV Drug	Total	IV Drug	Total	IV Drug	Total
New HIV Infections						
1988	122,084	177,929	83,762	137,187	−31.4%	−22.9%
1989	111,320	146,965	69,103	102,100	−37.9	−30.5
1990	91,445	119,642	52,213	78,367	−42.9	−34.5
1991	68,867	94,955	37,119	60,755	−46.1	−36.0
1992	49,113	74,098	25,586	47,871	−47.9	−35.4
1993	44,024	68,401	22,481	43,887	−48.9	−35.8
1994	39,040	62,568	19,729	40,072	−49.5	−36.0
1995	34,456	56,971	17,390	36,573	−49.5	−35.8
2000	20,147	37,184	11,018	24,734	−45.3	−33.5
New AIDS Cases						
1988	10,159	38,967	9,496	38,284	−6.5%	−1.8%
1989	15,628	53,826	14,171	52,313	−9.3	−2.8
1990	22,955	70,724	20,141	67,787	−12.3	−4.2
1991	31,693	87,055	26,846	81,977	−15.3	−5.8
1992	41,190	101,158	33,632	93,217	−18.3	−7.9
1993	50,354	111,596	39,575	100,236	−21.4	−10.2
1994	57,955	117,680	43,795	102,710	−24.4	−12.7
1995	63,123	119,749	45,893	101,467	−27.3	−15.3
2000	56,363	95,381	35,656	72,586	−36.7	−23.9
Deaths from AIDS during Year						
1988	5,828	23,764	5,536	23,464	−5.0%	−1.3%
1989	9,173	34,098	8,490	33,392	−7.4	−2.1
1990	13,903	46,752	12,498	45,290	−10.1	−3.1
1991	20,052	60,979	17,472	58,100	−12.9	−4.7
1992	27,386	74,888	23,093	70,388	−15.7	−6.0
1993	35,381	87,710	28,845	80,839	−18.5	−7.8
1994	43,261	98,188	34,078	88,505	−21.2	−9.9
1995	50,204	105,737	38,216	93,058	−23.9	−12.0
2000	59,086	103,819	39,221	82,247	−33.6	−20.8

TABLE 33

EFFECT OF VARIATIONS IN SIZE OF HETEROSEXUAL POPULATION BASED ON MIDDLE-PROJECTION ASSUMPTIONS

Year	Middle Projection		33-1/3% Smaller Heterosexual Population			
			Number		Percentage Change	
	Heterosexual	Total	Heterosexual	Total	Heterosexual	Total
New HIV Infections						
1988	25,490	177,929	25,488	177,927	−0.01%	*
1989	22,120	146,965	22,135	146,980	0.07	0.01%
1990	16,904	119,642	16,894	119,633	−0.06	−0.01
1991	17,122	94,955	17,104	94,938	−0.11	−0.02
1992	16,720	74,098	16,693	74,072	−0.16	−0.04
1993	16,871	68,401	16,832	68,362	−0.23	−0.06
1994	16,782	62,568	16,732	62,518	−0.30	−0.08
1995	16,490	56,971	16,429	56,910	−0.37	−0.11
2000	13,667	37,184	13,567	37,084	−0.73	−0.27
New AIDS Cases						
1988	1,784	38,967	1,786	38,968	0.11%	*
1989	2,842	53,826	2,844	53,827	0.07	*
1990	4,287	70,724	4,288	70,725	0.02	*
1991	6,035	87,055	6,035	87,056	0.00	*
1992	7,958	101,158	7,957	101,158	−0.01	*
1993	9,866	111,596	9,864	111,594	−0.02	*
1994	11,552	117,680	11,550	117,678	−0.02	*
1995	12,862	119,749	12,859	119,745	−0.02	*
2000	15,138	95,381	15,115	95,358	−0.15	−0.02%
Deaths from AIDS during Year						
1988	994	23,764	995	23,765	0.10%	*
1989	1,624	34,098	1,625	34,099	0.06	*
1990	2,538	46,752	2,538	46,753	0.00	*
1991	3,746	60,797	3,747	60,798	0.03	*
1992	5,206	74,888	5,207	74,889	0.02	*
1993	6,826	87,710	6,826	87,710	0.00	*
1994	8,472	98,188	8,471	98,187	−0.01	*
1995	10,001	105,737	9,999	105,735	−0.02	*
2000	14,274	103,819	14,259	103,804	−0.11	−0.01%

* Indicates less than 0.005%.

An annual growth rate of 1.35 percent of the 1983 population, reduced by the number of AIDS deaths, was used in making the basic projections. This growth rate was based on the actual growth rate from 1983 to 1984. To test the effect of variations in this rate, a projection was made by using the middle-projection assumptions except with an assumed population growth rate beginning in 1983 that was 50 percent larger, that is, 2.025 percent of the 1983 population. Table 34 shows that more rapid population growth would increase the number of new HIV infections by percentages reaching 20 percent by the year 2000. Most of this would come in the high-risk groups, although some would occur in heterosexuals because of the larger number of high-risk people.

Use of "Average" Number of Sexual and IV Drug Acts per Year

The model uses an "average" number of unprotected sexual and IV drug acts per year for each of the various categories and does not attempt to segregate the groups by degrees of promiscuity. The "average" numbers of such acts were not based on any studies, but instead were the numbers that were needed to reproduce the number of AIDS cases as reported by the CDC, assuming that the other assumptions used in the model were correct.

In this respect, the use of the word "average" may be misleading. For example, if a monogamous person has 200 sexual episodes with his equally monogamous (and uninfected) partner in a year and a promiscuous person has sex once each with 20 persons of unknown infectivity in the same year, the average number of sexual acts by these two persons in 110 per year. Yet the technique used in validating the model probably would result in an "average" number of acts of about 20, in order to validate to the actual data.

To carry the point further, if in the next year the monogamous couple decided to completely refrain from sex, but the promiscuous person doubled his sexual activity, the actual average number of sexual acts per person would be reduced from 110 to 20. However, the effective "average" for purposes of modeling the spread of the virus presumably would double. Further discussion of the relative risk levels of monogamous and non-monogamous sexual activity follows.

In projecting the epidemic, the figures being used as "average" numbers of sexual or IV drug acts should be viewed as the "effective" average, which might vary from the "actual" average because of different changes in the amount of sexual or IV drug activity by persons with differing risk

TABLE 34

COMPARISON OF MIDDLE PROJECTION WITH PROJECTION ASSUMING 50% MORE RAPID POPULATION GROWTH

Year	Middle Projection	50% More Rapid Population Growth	Percentage Increase 50% Increase to Middle
		New HIV Infections	
1988	177,929	181,846	2.2%
1989	146,965	152,365	3.7
1990	119,642	125,969	5.3
1991	94,955	101,376	6.8
1992	74,098	79,962	7.9
1993	68,401	74,841	9.4
1994	62,568	69,433	11.0
1995	56,971	64,123	12.6
2000	37,184	44,681	20.2
		New AIDS Cases	
1988	38,967	39,016	0.1%
1989	53,826	53,941	0.2
1990	70,724	70,962	0.3
1991	87,055	87,498	0.5
1992	101,158	101,904	0.7
1993	111,596	112,745	1.0
1994	117,680	119,321	1.4
1995	119,749	121,940	1.8
2000	95,381	99,998	4.8
		Deaths from AIDS during Year	
1988	23,764	23,786	0.1%
1989	34,098	34,151	0.2
1990	46,752	46,867	0.2
1991	60,797	61,023	0.4
1992	74,888	75,292	0.5
1993	87,710	88,371	0.8
1994	98,188	99,186	1.0
1995	105,737	107,148	1.3
2000	103,819	107,593	3.6
		HIV+ Persons at End of Year	
1988	1,183,317	1,191,685	0.7%
1989	1,296,184	1,309,899	1.1
1990	1,369,075	1,389,001	1.5
1991	1,403,233	1,429,354	1.9
1992	1,402,443	1,434,023	2.3
1993	1,383,134	1,420,493	2.7
1994	1,347,514	1,390,740	3.2
1995	1,298,748	1,347,714	4.1
2000	974,461	1,046,421	7.4

levels. For example, the efforts on AIDS education among heterosexuals might reduce the level of sexual activity most among those who already are careful in choosing their sexual partners and therefore are least at risk, whereas those who are at higher risk (because of contact with IV drug users, for example) may be less influenced by educational efforts.

The "average" can be affected by the estimates being used for the probability of infection from a sexual or IV drug act with an infected partner. Thus if the actual risk from a single act of anal sex is in fact twice that being assumed, the "average" number of acts of anal sex during a year would have to be reduced by approximately 50 percent to give the same resulting number of HIV infections. There is little effect on the validation process or on the projections from overstating the number of sexual or IV drug acts and correspondingly understating the frequency, or vice versa.

Measurement of Risk of Sexual Activity

The projections in this paper assume various changes in the frequency of the different types of sexual and IV drug activity. As shown by comparison of the high, middle, and low basic projections, variations in these frequencies can have a significant effect in the long-range projections of the epidemic. Because people generally base their actions in part on the level of risk involved, if the reasonableness of these assumptions is to be evaluated, it is important to measure the risk levels of the various types of sexual activity.

In measuring these risk levels, several factors must be considered:

1. The probability that one's partner is infected
2. The probability that the infection will be transmitted by a single act of sex with an infected partner
3. The frequency with which sexual activity takes place
4. The number of sexual partners one has.

Obviously, one factor in determining the risk of becoming infected is the type of sexual partner. The person who has a monogamous relationship with an uninfected partner has no chance of infection from sexual contact. Conversely, the person with a monogamous relationship with an infected partner has a high risk. In between these extremes are those with single or multiple partners of unknown infectivity.

Several studies, generally among homosexuals, have shown a correlation between the number of sexual partners and the probability of being HIV+. These studies suggest that persons stand a greater risk of HIV infection if

they have multiple partners. Clearly, if having multiple partners means that one's choice of partners is more apt to include those who might be infected, multiple partners involve a higher risk for a given number of sexual acts. However, it is important in understanding the epidemic to examine the mathematics of the risk levels of single versus multiple partners for both homosexuals and heterosexuals, based on the assumption that the probability that one's partner is infected is the same whether he or she has single or multiple partner relationships.

For a monogamous relationship, the probability of HIV infection for a given number of sexual acts may be determined by the formula:

$$i \times [1 - (1 - p)^n]$$

where

i = the probability that one's sexual partner is infected
p = probability of infection from a single act of sex with an infected partner
n = the number of sexual acts during the period.

On the other hand, for the person with multiple partners, the probability of an HIV infection for a given number of sexual acts is as follows, assuming that one's partners are chosen at random from among the pool of persons in the risk group (that is, that there is not some element of monogamy involved):

$$1 - [1 - (i \times p)]^n$$

The probability that one's sexual partner is infected depends of course on one's judgment in choosing such partners as well as on geographical and other factors. If we assume that a person is choosing a partner totally at random from a given risk group, the model can determine this probability based on the ratio of the number of persons in the group with HIV infections to the total population in the group. The probability of transmitting the virus from a single sexual act with an infected partner was discussed earlier.

Table 35 shows a comparison of the risk from a single sexual act for the various risk categories. The figures are developed by multiplying the risk factor for a single act of sex with an infected partner, discussed earlier, by the ratio of the modeled number of HIV-infected persons in the group to the total number of persons in the group. For homosexuals, figures are shown based on 1982 data, based on current data, and using the heterosexual risk factor.

TABLE 35

MEASUREMENT OF RISK LEVELS PER SINGLE SEXUAL ACT

Category	Risk Factor	Number in Population Group		Probability of Infection: One in:
		HIV+	Total	
Homosexual Men				
1982 data	0.01	106,898	2,533,000	2,370
Current data	0.01	467,213	2,703,000	579
Heterosexual risk factor	0.00125	467,213	2,703,000	4,628
Heterosexual Men				
Partner Not High-Risk				
White	0.00125	29,974	81,514,000	2,175,592
Black	0.00125	10,354	10,726,000	828,743
Other	0.00125	18,702	7,973,000	341,054
Total	0.00125	59,030	100,213,000	1,358,130
Partner IV Drug User				
White	0.00125	24,228	47,000	1,552
Black	0.00125	65,120	135,000	1,658
Other	0.00125	20,265	42,000	1,658
Total	0.00125	109,613	224,000	1,635
Heterosexual Women				
Partner Not High-Risk				
White	0.00125	5,218	72,328,000	11,089,000
Black	0.00125	8,557	8,424,000	787,566
Other	0.00125	3,547	6,603,000	1,489,259
Total	0.00125	17,322	87,355,000	4,034,407
Partner IV Drug User				
White	0.00125	87,935	170,000	1,547
Black	0.00125	186,703	386,000	1,654
Other	0.00125	115,266	237,000	1,645
Total	0.00125	389,904	793,000	1,627

Several points about the figures shown in Table 35 are worth noting:

1. Homosexual activity and sexual activity with IV drug users represent a significant risk of infection (although even in such a "high-risk" situation, the risk of infection from a single act is far from a certainty).
2. On the other hand, heterosexual activity with someone not in a high-risk group involves only an extremely remote risk—so remote, in fact, that it has been said that "the risk from AIDS from a low-risk sexual encounter is about the same as being killed in a traffic accident while driving 10 miles on the way to that encounter" [6].
3. Risk levels among heterosexuals vary considerably by race. This is because substantially higher proportions of nonwhites are assumed to be IV drug users and bisexuals and have already spread the infection to the heterosexual community (see Table 9). (The risk levels do not vary significantly by race for the high-risk groups because the assumed distribution by race of these persons was based on the number

of AIDS cases reported to date. However, note the comments on this assumption elsewhere in this section.)

As mentioned earlier, the risk factor of 0.01 for homosexuals is only estimated. However, this factor results in a 1982 level of homosexual activity approximately two and one-half times that of heterosexuals. A smaller risk factor would require a still higher level of homosexual activity for the homosexual AIDS cases to validate properly. Also, the risk factor for female-to-male transmission may be less than 0.00125, thus reducing the probabilities of infection for heterosexual males.

Table 36 compares the probability of infection from multiple sexual acts for monogamous situations with those involving multiple partners, based on the formulas shown above. The right-hand column shows the ratio of the risk in the multiple-partner situation to that in the single-partner situation.

The sharp contrast in risk levels shown in Table 35 is apparent in Table 36 also. However, the most significant point demonstrated in Table 36 is the additional risk arising from multiple sex partners. For homosexual men, an already very high risk is increased significantly. In fact, it is multiplied severalfold for the person with a very large number of sexual partners over a period of time. However, for the heterosexual not involved with high-risk persons, an extremely small risk is increased only very slightly. Even for someone with 50 sexual episodes each with a different partner, the risk is only 3 percent greater than for the person who has 50 episodes with the same partner. As the third part of Table 36 shows, the reason for this is the much lower risk factor for heterosexuals.

Table 36 shows that data on the added risk of multiple sexual relationships taken from studies of homosexuals may be of significant value in analyzing the spread of HIV infection among that risk group, but it cannot be applied to heterosexuals. Instead, heterosexual activity with multiple sex partners increases the risk of infection over that from sexual activity with a single partner only slightly, unless it increases the probability of sexual activity with a high-risk partner (or if it results in an increase in the total number of sexual acts).

The behavioral assumptions shown in the middle and low projections in Table 15 reflect the above analysis of risk levels. For homosexuals, it has been assumed that there will be substantial futher reductions in anal sexual activity, reflecting the very high risk involved. Similarly, for IV drug users, it is assumed that educational efforts eventually will result in fairly significant reductions in sharing of needles. For heterosexuals, considerably less

TABLE 36

MEASUREMENT OF RISK LEVELS FOR MULTIPLE SEXUAL ACTS

Number of Acts	Probability of Infection: One in:		Risk Ratio: Multiple to Single
	Single Partner	Multiple Partners	
Homosexual Men, 1982 Data			
20	130	119	1.09
50	60	48	1.25
100	37	24	1.54
200	27	12	2.22
500	24	5	4.54
Homosexual Men, Current Data			
20	32	29	1.08
50	15	12	1.21
100	9	6	1.45
200	7	3	1.95
500	6	2	3.37
Homosexual Men, Current Data, Heterosexual Risk Factor (0.00125)			
20	234	232	1.01
50	95	93	1.03
100	49	47	1.05
200	26	24	1.11
500	12	10	1.27
Heterosexual Men, Partners Not in High-Risk Group			
20	50,000	50,000	1.01
50	20,408	20,000	1.03
100	10,638	10,000	1.06
200	5,650	5,000	1.13
500	2,688	2,000	1.34
Heterosexual Men, Partners IV Drug Users			
20	82	82	1.01
50	34	33	1.02
100	17	17	1.03
200	9	9	1.06
500	4	4	1.16
Heterosexual Women, Partners Not in High-Risk Group			
20	200,000	200,000	1.01
50	83,333	83,333	1.03
100	43,478	40,000	1.06
200	22,727	20,000	1.13
500	10,870	8,065	1.34
Heterosexual Women, Partners IV Drug Users			
20	82	82	1.01
50	34	33	1.02
100	17	17	1.03
200	9	9	1.06
500	4	4	1.16

percentage reduction is shown, reflecting the low actual risk levels of heterosexual activity, although some reductions still are assumed because of the general public concern about the epidemic. However, the heterosexual discrimination factors assume that public education will eventually persuade most heterosexuals to avoid the much higher risk of sexual activity with IV drug users and, to a lesser extent, bisexuals.

Variations in HIV Seroprevalence by Race

As mentioned earlier, the projections assume that the total homosexual, bisexual, and IV-drug-using populations are split by race in proportion to the number of AIDS cases diagnosed to date. However, there is evidence that this assumption may understate the white high-risk populations and correspondingly overstate the black and other high-risk populations. The 1987 CDC report [3] lists three studies of homosexual and bisexual men and three studies of IV drug users in which the percentage of HIV+ persons was shown by race. The black-to-white ratios of percentages of persons infected range from a low of 1.7 to 1 to a high of 3.4 to 1 for homosexuals and bisexuals, and from a low of 1.7 to 1 to a high of 5.1 to 1 for IV drug users.

For hispanics, similar figures occurred for IV drug users; however, the only study that showed ratios of hispanics to whites for homosexuals and bisexuals showed a ratio of only 0.9 to 1.

The assumption referred to above was made in spite of these studies, because the studies are limited in scope and because their results do not translate into usable assumptions for the model. However, when reviewing those projections that are split by race, the failure of the model to allow for variations by race in the proportions currently infected should be kept in mind.

Overstatement of Epidemic Because of Failure to Segment

Some models have segmented the population by geographic region, degree of promiscuity, or other characteristic. As previously mentioned, this model treats all persons within a category as a single group and does not attempt to segment them. This has the effect of overstating the number of HIV infections, because it fails to take into account the fact that, to some degree or another, the epidemic may be limited or contained within a subgroup.

To try to estimate the degree of this overstatement, tests were run by using a simplified model based on the same general approach as the regular model,

but with three segmented populations: one with a high initial level of infection, one with a medium level, and one with a low level. The results showed that, so long as the proportion of infected persons in a subgroup was about 10 percent or less, combining the various subgroups into a single group had virtually no effect on the total number of cases projected, but that some error began to develop at levels significantly in excess of 10 percent.

For the projections of the heterosexual cases, therefore, the failure to segment would appear to be insignificant, because there is no evidence that any portion of the heterosexual community is going to have more than a very small percentage of HIV+ persons.

For homosexuals, bisexuals, and IV drug users, however, the projections presented here could overstate the epidemic, to the extent that it will be possible to contain the epidemic within any subgroup of these categories. For example, if a large proportion of the homosexual population in one or more major cities became infected, but only a small portion of the homosexual population in other major cities was infected, use of the model on a national basis could overstate the spread of the epidemic. (The model segregates data by race, and therefore different levels of saturation by race will not create any distortion except because of the racial variations in percentage infected, discussed above.)

The 1987 CDC report [3] discusses a large number of studies in many different states that determined the percentage of different groups that were HIV+. These percentages varied widely. These figures cannot be translated into usable data for this paper because the studies generally involve special categories of persons, such as those reporting to an STD clinic, and therefore may not be representative of the risk group as a whole.

To the extent that persons are age-selective in determining their sexual or IV drug partners, the failure to segment by age could also have some effect, although probably not very much.

Although the model cannot directly allow for this problem without developing projections separately by region and age group, it can be allowed for indirectly by being slightly more optimistic than would otherwise be the case in setting the behavioral assumptions. The behavioral assumptions shown for the middle projection in Tables 12 and 15 indicate a reduction in the frequency of IV drug activity from 55 in 1982 to 20 for 1992 and subsequent. Although much of this reduction is based on the assumption of a significant reduction in the sharing of infected needles by IV drug users, some of it should be attributed to the failure to allow for the geographical or other segmentation of high-risk persons.

General

A model is of little value if it requires data that are unavailable or cannot be estimated with reasonable accuracy. The modeling approach in this paper attempts to make use of the major relevant factors in the AIDS epidemic. In doing so, it uses available data, but necessarily must make certain approximations, either because of lack of data or because the complexity of calculation would not be worth the additional refinements in the results, or both. Several such approximations are as follows:

1. Prostitution. No special segmentation has been made for either male or female prostitutes. For male prostitutes, it is doubtful whether any reliable date are available regarding their effect, if any, on the epidemic in past years. There is little evidence that female prostitutes are a significant factor in the spread of the epidemic, even though a portion of street prostitutes are HIV+ (primarily from IV drug use), because their sexual practices generally either involve oral sex or the use of condoms and because the female-to-male transmission efficiency is very low. For both types, the validation process automatically takes into account those persons who are sexually very active as well as those who are less active, and thus should allow for all sexual activity regardless of the financial arrangements involved.
2. Segregation by age and aging of the population. As already discussed, the model does not attempt to segregate the population by age, except that persons under age 16 are excluded. As Table 33 demonstrated, variations in the size of the heterosexual population have no effect on the projections. The model also does not directly allow for movement of children into the IV drug or homosexual/bisexual populations as they become adults; however, the population growth factor does so indirectly to some degree, and Table 34 shows the results of variations in that factor.
3. Absence of interracial sex or needle-sharing segregation between the homosexual/bisexual group and the IV drug group, and the assumption that those in the high-risk groups do not become infected from vaginal sex. These approximations were made because it was thought that taking these factors into account would have little effect on the projections, and in any event there does not appear to be any reliable data available from which to refine the model in any of these respects.
4. Other sources. Because the model relates only to HIV infections arising from sexual and IV drug activity, it does not reflect HIV infections within this group from persons who became infected from other sources such as blood transfusions. Such infections are believed to constitute a minor and diminishing source of sexual and IV-drug-related HIV infection, because many if not most such sources of infection now know of their HIV status. In any event, the validation process accounts for such cases.

Comparison of Model Projections with Other Projections

Based on AIDS cases diagnosed through July 1987, the CDC has estimated that the cumulative number of cases diagnosed will be 365,000 through 1992 and 450,000 through 1993. The middle projection shows 419,000 cases through 1992 and 530,000 through 1993. There may be several reasons for this difference:

1. The CDC may have underestimated the number of cases and may eventually raise its estimate based on later data.
2. The change in the definition of AIDS in September 1987 may have caused an overstatement of the recent levels of sexual and IV drug activity developed during the validation process. It also may have had some effect on the development of the aging factors, although the exact impact is not clear. The validation process is of relatively little value in determining levels of sexual and IV drug activity for the most recent couple of years because of the time between HIV infection and the development of AIDS.
3. Other factors, such as variations in the assumed scale of progression rates, could cause the estimates to differ.

Cowell and Hoskins [5] also projected the cumulative number of AIDS cases, based on three alternative scenarios:

1. HIV infections continue until 100 percent of the high-risk groups are infected.
2. New infections decline to zero by 1997.
3. No new infections occur after 1987.

Their projections related only to the high-risk groups and did not include heterosexual cases. A comparison of their projections with the basic projections shown in Table 16 is shown in Table 37.

In making their estimates of the cost of the AIDS epidemic to the insurance industry, Cowell and Hoskins used the assumption that the number of new HIV infections would decrease to zero by 1997. As Table 37 indicates, the cumulative number of HIV infections and AIDS cases by the year 2000 under the middle projection is about 400,000 HIV infections and 250,000 AIDS cases less than that used by Cowell and Hoskins, even though the middle projection includes more than 130,000 heterosexual AIDS cases, while Cowell and Hoskins excluded them. This suggests that Cowell and Hoskins may not have sufficiently allowed for changes in sexual and IV drug behavior that have already taken place and that will take place in the next few years.

TABLE 37

COMPARISON OF BASIC PROJECTIONS WITH COWELL-HOSKINS PROJECTIONS

	Basic Projections			Cowell-Hoskins Projections		
Year	Low	Middle	High	Infections Continue to 100% of High-Risk Groups	New Infections Decline to 0 by 1997	New Infections Stop in 1987
			New HIV Infections			
1988	172,817	177,929	177,929	304,623	271,873	0
1989	121,756	146,965	188,745	349,432	273,764	0
1990	75,108	119,642	185,836	372,330	256,127	0
1991	37,689	94,955	171,762	366,809	224,621	0
1995	23,090	56,971	108,383	173,190	68,714	0
2000	15,573	37,184	82,011	30,033	0	0
			Cumulative HIV Infections			
1988	1,238,364	1,243,476	1,243,476	1,224,189	1,191,439	919,566
1989	1,360,120	1,390,441	1,432,221	1,573,621	1,465,203	919,566
1990	1,435,228	1,510,083	1,618,057	1,945,951	1,721,330	919,566
1991	1,473,917	1,605,038	1,789,819	2,312,760	1,945,951	919,566
1995	1,575,756	1,867,076	2,304,787	3,331,952	2,451,692	919,566
2000	1,666,982	2,086,867	2,756,168	3,687,388	2,485,433	919,566
			Cumulative AIDS Cases			
1988	105,897	105,897	105,897	76,182	76,182	76,182
1989	159,708	159,723	159,723	118,354	118,255	117,440
1990	230,295	230,447	230,572	176,780	176,062	171,162
1991	316,781	317,502	318,327	255,092	252,266	236,244
1995	746,184	767,685	797,877	821,073	755,065	533,821
2000	1,176,887	1,304,982	1,495,369	1,937,640	1,554,819	748,409

For the year 2000 the high projection shows cumulative AIDS cases slightly less than Cowell and Hoskins used. However, under this scenario the number of cumulative HIV infections is substantially larger than that projected by Cowell and Hoskins, for two reasons: First, the high projection assumes a continuing and relatively high level of new HIV infections, whereas the Cowell-Hoskins projection assumes that new HIV infections decrease to zero by 1997. Second, the progression rates from HIV+ to AIDS used by Cowell and Hoskins are more rapid than those used in the model projections, so more AIDS cases are generated for a given number of HIV infections under the Cowell-Hoskins projection.

VII. CONCLUSION

This paper presents a model that projects the portion of the AIDS epidemic related to sexual and IV drug behavior, based on information currently available. The model uses several tools:

1. Analysis of the various risks involved
2. Development of a cohort-based approach for moving from one stage of illness to another
3. Analysis of process and data to produce a usable model
4. Analysis and interpretation of data from various sources
5. Judgmentally driven assumption setting
6. Validation of results with known data.

The model should be valuable in three ways:

1. The mathematical process should be of value in developing a variety of projections of the epidemic, both nationally and locally.
2. The basic projections should be a good estimate of the progression of the epidemic, based on current knowledge.
3. The ability of the model to do sensitivity analysis should be of value independently of the accuracy of the basic projections.

As new information is developed and additional data are gathered, it should be possible to enter them into the model and then to develop new and even more reliable projections.

As the number of AIDS cases increases substantially in the next few years, pressures to take additional steps to cope with the epidemic may increase. Because the model is based on the sexual and IV drug behavior that accounts for nearly all new HIV infections, it should be useful in quantifying the effect of the actions taken by government officials and others to modify these behavioral patterns. It also should be useful to other organizations whose business is in some way affected by the progress of the epidemic.

Finally, the model should be helpful in demonstrating that, although certain groups of persons will be very seriously impacted, the epidemic will not spread generally throughout the population. We should approach the AIDS problem with this realization, so that resources can be properly directed and the proper public policies established.

REFERENCES

1. "Acquired Immunodeficiency Syndrome (AIDS) among Blacks and Hispanics—United States," *Centers for Disease Control Morbidity and Morality Weekly Report* 35, No. 42 (October 24, 1986): 655–58, 663–66.
2. BRODT, H.R., HELM, E.B., WENER, A., JOETTEN, A., BERGMANN, L., KLUVER, A., AND STILLE, W. "Spontanverlauf der LAV/HTLV-III-Infektion; Verlaufsbeobachtengen bei Personen aus AIDS-Riskogruppen," *Deutsche Medizinische Wochenschrift, Stuttgart* III (1986): 1175–80.
3. CENTERS FOR DISEASE CONTROL. "G. Cases of AIDS and Case-Fatality Rates by Half-Year of Diagnosis, United States," *AIDS Weekly Surveillance Report*, July 20, 1987.
4. CENTERS FOR DISEASE CONTROL. *Human Immodeficiency Virus Infections in the United States: A Review of Current Knowledge and Plans for Expansion of HIV Surveillance Activities*. Washington, D.C.: Department of Health and Human Services, Public Health Service, November 30, 1987.
5. COWELL, M.J. AND HOSKINS, W.H. "AIDS, HIV Mortality and Life Insurance." In *The Impact of AIDS on Life and Health Insurance Companies: A Guide for Practicing Actuaries, Report of the Society of Actuaries Task Force on AIDS*. Reprinted in *TSA* XL, Part II (1988): 909–72.
6. HEARST, N. AND HULLEY, S.B. "Preventing the Heterosexual Spread of AIDS. Are We Giving Our Patients the Best Advice?", *Journal of the American Medical Association* 259, no. 16 (April 22–29, 1988): 2428–32.
7. KINSEY, ALFRED C. ET AL. *Sexual Behavior of the Human Male*. Philadelphia: Saunders, 1948.
8. PADIAN, N. ET AL. "Male-to-Female Transmission of Human Immunodeficiency Virus," *Journal of the American Medical Association* 258, no. 6 (August 14, 1987): 788–90.
9. "Study: Risk of AIDS Progression Rises Each Year after Infection," *AIDS Alert* 2, no. 4 (April 1987): 57–58. Atlanta, Ga.: American Health Consultants, Inc.

DISCUSSION OF PRECEDING PAPER

MICHAEL J. COWELL:

The General Accounting Office Report to Congress on "AIDS Forecasting" classifies mathematical models of HIV infection and AIDS as follows:

- Extrapolation
- Back calculation
- Macro-level simulation
- Micro-level simulation [1].

To date, models of the epidemic developed by the actuarial profession in North America and the UK [2], [4], [8] and [9] have incorporated aspects of one or more of the first three categories of techniques. Micro-level simulation incorporates assumptions of rates of transmission of HIV, patterns of behavior that put uninfected people at high risk for infection, and the interrelationship of transmission patterns among subpopulations at risk, each with its own set of rates of transmission and prevalence.

Mr. Plumley's paper, the first actuarial work to incorporate micro-level simulation, gives us specific insights into issues that have only been alluded to in previous papers, and it adds a number of valuable perspectives to the process of forecasting the spread of the epidemic.

To the extent that his results closely parallel those of other models in the actuarial and the general literature on this subject, Mr. Plumley's methodology and assumptions appear both sound and plausible.

This discussion emphasizes the principal points with which I am in broad general agreement with Mr. Plumley on the numerical aspects of his work, and highlights those few areas where I believe further analysis is required to substantiate certain of his conclusions.

1. ESTIMATES OF HIV INFECTION

First, I share Mr. Plumley's assessment of the extent of HIV infection and, within a tolerable range of estimation error, his estimate of current HIV infections and projection of AIDS cases and deaths.

His estimate that at year-end 1988 there were about 1.2 million persons in the U.S. infected with HIV is the same as that projected in 1987 by Cowell and Hoskins [2], and is consistent with the broader range of 800,000 to 1.5 million as of mid-1987 suggested by Panjer [8] and also with the recent refinements by CDC of its earlier estimate of 1 million to 1.5 million [3].

Mr. Plumley's estimates are also consistent with those made by the CDC in its November 1987 analysis of HIV infection, which was developed from the limited knowledge then available of the prevalence of the disease among known groups at high risk [5].

2. PROGRESSION FROM HIV INFECTION TO AIDS

In comparing his model to that of Cowell and Hoskins, Mr. Plumley observes that the rates we used for progression from initial HIV infection to AIDS are more rapid than those used in his model. Although we used the data from the Frankfurt Study, with its faster progression to AIDS, as the basis for our Markov process, our long-range forecast was based on the same progression he uses, as developed from the CDC/San Francisco City Clinic data. These data showed a mean time of progression of 9.3 years, compared to the 7.2 years from the Frankfurt Study. Recent analysis by Longini et al. [6] of the CDC/San Francisco data suggests a mean progression of 9.8 years, although differences this small have no significant impact on the overall thrust of our conclusions or Mr. Plumley's.

Patterns of progression from initial HIV infection to AIDS are becoming well identified and, with the possible exception of mortality from the point of clinically diagnosed AIDS, are generally less of a controversy than are other aspects of forecasting the epidemic.

3. FORECASTING AIDS CASES

The table on the next page compares total U.S. AIDS cases from Mr. Plumley's model to those from Cowell and Hoskins [2] and to actual cases reported to CDC through 1989.

CUMULATIVE AIDS CASES—REPORTED, MODELED AND PROJECTED (000's)

Year	AIDS Cases Reported to/ Projected by CDC* by Year-end	Cowell/Hoskins AIDS Cases If:		Plumley AIDS Cases (Table 16)	
		HIV Spread Declines to Zero by 1977	HIV Spread Had Stopped in 1987	Low Projection	Middle Projection
1986	29	27	27	40	40
1987	50	47	47	67	67
1988	80	76	76	106	106
1989	118	118	117	160	160
1990	173	176	171	230	230
1991	236	252	236	317	318
1992	308	349	310	416	419
1993	390	466	389	525	530
1995		755	534	746	768
2000		1,555	748	1,177	1,305

*Reported AIDS cases through 1989 are from CDC's *AIDS Weekly Surveillance Reports* through 1988, replaced by *Monthly HIV/AIDS Surveillance Reports* commencing March 1989. CDC Projections are from reference [3].

Mr. Plumley suggests that Cowell and Hoskins may not have sufficiently allowed for changes in sexual and IV drug behavior that have already taken place and that will take place in the next few years.

It is true that we did not make explicit provision for the spread of HIV infection into the general heterosexual population. This was not because we assumed it would be zero; rather, we did not want to adjust our model, which was based on information available in early 1987 on high-risk groups about which we knew something, for assumptions about HIV prevalence in the general heterosexual population about which little was known at that time.

Now that information is becoming available for this group, it certainly makes sense to include it in current modeling efforts, and on the basis of the data developed over the past three years, I would certainly concur with Mr. Plumley's quantification of the likely extent of infection in this group.

The Cowell/Hoskins projection based on the assumption that the spread of HIV stopped at the end of 1987 was obviously not intended as an estimate *per se*. Rather, it was the base line from which to measure the impact of new infections in 1988 and subsequently. Nevertheless, when measured against actual cases reported to CDC, and CDC's latest estimates through 1993, it appears to produce a closer fit than Mr. Plumley's.

4. OTHER OBSERVATIONS

In allocating groups at high risk of infection by race (Table 9), Mr. Plumley develops percentages for each male high-risk group as a percentage of the total male population as follows:

	Percentage of White Males	Percentage of Black Males	Ratio: Black to White
Homosexuals	2.67%	4.11%	1.54
Bisexuals	1.65	6.55	3.97
IV Drug Abusers	0.23	3.96	17.22

That IV drug abuse should be 17 times higher among black males than among white males seems surprising, but plausible, given the predominantly inner-city nature of this problem. It is difficult, however, to explain the much higher assumptions on homosexual and bisexual behavior among blacks. In subsequent discussion of variations in HIV prevalence by race, Mr. Plumley acknowledges that his assumption may understate the white and overstate the black populations at high risk. Most likely, these assumptions do not have a major bearing on his conclusions, but they should be clarified lest they detract from the credibility of his overall analysis.

In comparing the results of Table 21 to Table 22, Mr. Plumley observes that new HIV infections among (non-IV drug abusing) heterosexuals would be reduced by their ". . . merely avoiding sexual activity with those in the high-risk groups . . . ". Although this appears to state the obvious, its practical implications may not be as readily achieved. Recent analysis by CDC of the results of HIV testing among 2 million nonmilitary people showed about 130,000 infected with the virus, but fewer than one in seven of those infected acknowledging that they were aware of their HIV status.

Anecdotal evidence, including stories that have received national press coverage, tends to confirm that many non-IV-drug-abusing heterosexuals who have tested positive do not learn the HIV status of the person infecting them until it is too late. As indicated above, I concur in Mr. Plumley's quantification of the likely extent of HIV infection among non-IV-drug-abusing heterosexuals. My major disagreement is with his phrasing, namely, that the disease ". . . will *only* strike about one-tenth of one percent of the heterosexual population . . ." (italics mine). I have difficulty accepting the unnecessary death of 200,000 or more people, many of them in the prime of life, just as I have difficulty rationalizing the deaths of 350,000 people

annually from diseases related to smoking, albeit that a much higher percentage of the latter group are more advanced in age. In both cases, premature death could have been averted by adhering to healthy lifestyle practices.

Mr. Plumley and I come to the same general conclusion, namely, that the disease will continue to have its most significant impact on a few subpopulations and that it will not likely spread generally throughout the entire population. Some have even suggested that because of this, it cannot be labeled an epidemic in the strictest meaning of the word (that is, a disease that is "among the people"), though no rational observer would argue that it is not epidemic among certain groups of the population.

Where we perhaps differ is that I would emphasize more strongly than Mr. Plumley the advantages to containing the spread of HIV infection that come from education. There is evidence that the uninfected segments of the homosexual and bisexual population have taken steps to greatly reduce their risk of infection, although the IV-drug-abusing population appears as difficult to reach about the dangers of HIV infection as it is about the dangers inherent in drug abuse itself.

As to the risk to the general heterosexual population, I cannot match the rationale of the noted Princeton epidemiologist Robert May:

"... we should, in principle, multiply the infinitesimal probability of transmitting infection by the number of potential infectees, each with a normal life expectancy, and weigh this against the shortened life expectancy of the infected individual. This would be an anguished calculation even if we knew the probability of transmitting infection by casual contact (10^{-4}?; 10^{-7}?), which we do not. It is paradigmatic of many similar social and political calculations that must deal with events that have a very low (and uncertain) probability of occurring, yet whose occurrence would be awful; what might be called 'zero times infinity' problems. Difficult though such problems are, I do not think it helps to define them out of existence by asserting that some event of very low probability simply cannot occur."[7]

In conclusion, my disagreement with Mr. Plumley on matters of more or less philosophical interpretation in no way detracts from my admiration for his pioneering scholarship in what was heretofore the virtually unexplored territory of the actuarial implications of this epidemic. His paper opens several avenues for further investigation, and we are indebted to him for this contribution to the literature.

REFERENCES

1. "AIDS Forecasting," *Report to Congressional Requesters*. Washington, D.C.: General Accounting Office, June 1989, p. 3.

2. COWELL, M.J., AND HOSKINS, W.H. "AIDS, HIV Mortality and Life Insurance." Chapter 3 in *The Impact of AIDS on Life and Health Insurance Companies: A Guide for Practicing Actuaries, Report of the Society of Actuaries Task Force on AIDS.* In *TSA* XL, Part II (1988): 909–72.
3. "Estimates of HIV Infection and Projected AIDS Cases: Summary of a Workshop, October 31–November 1, 1989," Centers for Disease Control, *Morbidity and Mortality Weekly Report* (February 23, 1990):110.
4. HOLLAND, D.M. "Part II. Observations on the Human Immunodeficiency Virus Epidemic and Managing Uncertainty in Insurance." Paper presented at the 23rd Actuarial Research Conference, University of Connecticut, Storrs, Conn., August 25-27, 1988.
5. "Human Immunodeficiency Virus Infection in the United States," *Report to the Domestic Policy Council.* Atlanta, Ga.: Centers for Disease Control, November 1987.
6. LONGINI, I.M., JR. ET AL. "Statistical Analysis of the Stages of HIV Infection Using a Markov Model," *Statistics in Medicine* VIII (February 1989): 831–43.
7. MAY, R.M. "HIV Infection in Heterosexuals," *Nature* 331 (February 25, 1988): 655–56.
8. PANJER, H.H. "AIDS: Some Aspects of Modeling the Insurance Risk," *TSA* XLI (1989): 199–222.
9. THE AIDS WORKING PARTY. *AIDS Bulletin No. 4.* London: Institute of Actuaries, March 1989.

CHARLES S. FUHRER:

This paper is a valuable contribution to the study of the AIDS epidemic. I have the impression that the estimates of the spread of the HIV infection in the U.S. in this paper are reasonably close to what has occurred and what will occur. I have the following three comments about the methodology and presentation of the paper.

1. FITTING TECHNIQUE

One of the more important sets of variables in the paper's model is the "Average Number of Unprotected Sexual and IV Drug Acts per Year." These are represented by the symbols D, H, B, A, and V (for IV drug acts, receptive anal intercourse by homosexuals, by bisexual males, by female heterosexuals, and penile-vaginal, respectively) in the formulas of Section 3. I believe the estimated values are presented in Table 12, but it would have been helpful if the author had used the symbols for the quantities, defined in the formula section, in the heading of this and various other tables. The paper tells us that these were estimated by using a trial-and-error process so that the resulting number of AIDS cases (using the assumed progression

rates from infection to AIDS) come as close as possible to the actual number of such cases for each category.

One problem with this procedure is that it is highly dependent on the author's judgment. No one else could reproduce these results. Also, I wonder what "as close as possible" means. The author does give us some information on how close he came, but every reader might wonder if he could have done better. Why wasn't some objective standard such as least squares used?

The values in Table 12 are suspiciously smooth. The D values look like they might fit to a quadratic; the H and B values are linear until they start leveling off as they get smaller; the A's are constant; and the P's are constant and then change to linear. These rates probably would tend to vary in a smooth way from year to year. Effectively the author has introduced implicit assumptions about their pattern. A far better method might have been as follows: First, try to assume that the values were constant. After getting the least squares (perhaps maximum likelihood would be better) value for the constant, check the goodness of fit. Then use a linear equation, estimate the two parameters, and determine whether the fit is improved. Next, a quadratic or other three-parameter curve could be tried. Perhaps the fit would be greatly improved by using one curve up to 1985 and a second thereafter. Then report in the paper the various models, how well they fit, and the final parameter values.

Incidentally, Cowell and Hoskins (ref. [5] in the paper) also used a similar trial-and-error method to fit their infectivity parameter a_i.

II. DESCRIPTION OF FORMULAS

I believe that the description of the formulas in the fourth part of Section III is difficult to understand and unnecessarily long. The author defines many variables that are then not used anywhere else in the paper. Actually, every formula is just an application of the formula:

$$\text{probability of infection} = [1-(1-ip)]^n,$$

which appears in Section VI of the paper. Here i is the probability that a sex (or drug) partner is infected. It was only necessary to inform the reader that the author used this formula with various stated assumptions about the prevalence of infectious acts for different risk groups and that i was taken to equal the number of infectious actives divided by total actives. He probably would want to add the formula for the number of people exposed by

category each year and explain that this number was multiplied by the probability of infection to yield the expected number of new infections each year by category.

III. BASING ESTIMATES ON ESTIMATES

A key assumption in the paper's model is the number of individuals in each of the high-risk groups. Unfortunately, very little is known about the size of some of these groups. The author was forced to use a 1948 reference (ref. [7] in the paper) to help guess the answer. Because the margin of error is great on these assumptions, I question how much we can trust the overall answers. Furthermore, the overall margin of error is hard to measure because estimates in these numbers are then used for further estimates.

The author does try to measure the effect on the projections of widely varying estimates of the size of the risk groups. The method was a little unclear, but I believe that he does not reestimate the number of unprotected acts based on these other risk group sizes.

There is potentially another method of doing this, if the author were willing to describe the pattern of number of acts with a two-parameter curve. In this case, the curve of the resulting incidence of AIDS cases could be only four parameters, even if one of them were to be the size of the risk group. (The reason that it would not be three parameters is that another one results from a boundary condition in the solution of the resulting differential equation. In other words, there is a parameter for the time location of the epidemic. Cowell and Hoskins derive the mathematics for this.) There may be enough data points in the history of the AIDS cases by calendar quarter to estimate a four-parameter curve by least squares or maximum likelihood. See Panjer [1] and [2] for how to use the maximum likelihood method for various progression rate distribution assumptions. He fits a two-parameter curve in [1] and a three-parameter in [2]. Note that Panjer did the curve-fitting for the total epidemic, but it would not be hard to adapt some of the methodology by risk group. I have fit such a four-parameter curve (so far only to the total AIDS cases) and obtained answers for the size of the infection surprisingly similar to those of the author's.

REFERENCES

1. PANJER, H.H. "AIDS: Some Aspects of Modeling the Insurance Risk," *TSA* XLI (1989): 199–222.
2. PANJER, H.H. "AIDS: Exponential vs. Polynomial Growth Models." Paper presented at the 23rd Annual Actuarial Research Conference, University of Connecticut, Storrs, Conn., August 1988.

RONALD GEBHARDTSBAUER:

I want to thank Mr. Plumley for writing this paper. It is evident that a great deal of thoughtful work went into it. In addition, I strongly support Plumley's thesis that continued and more extensive education is important to reducing the horrible effects of this disease. Even though I have been following this epidemic closely for eight years, I found the paper informative and the various projections intriguing.

There are some points that I would like to make—some are of a public policy nature. Because the paper could be used to aid public policy decision-making, words and ideas become very important (sometimes more important than the numbers). Thus, I contend that my critiques of the ideas are just as important as others' critiques of actuarial technique.

I of course only comment where I don't agree fully, but I would like to state that I was in agreement with Mr. Plumley many more times than I wasn't.

1. Shouldn't the "1 minus" before the p in the formulas be in front of the division and not in the numerator? [*Ed. note: This correction was made and the revised forumlas appear in this volume.*]
2. How do the progression rates (to AIDS and to death) include people who die of AIDS before they were diagnosed with AIDS? Are they ever diagnosed as having AIDS? Do they show up as an immediate death upon getting AIDS? Are they reflected at all?
3. As the paper points out, it is behavior (for example, unprotected receptive anal intercourse), not status (for example, being a gay male), that identifies one for being most at risk of becoming infected with HIV/AIDS. Therefore, I suggest that in categorizing the high-risk groups, words should describe behavior, not status. Some gay people have never participated in high-risk behaviors. In fact, sexual activity is not a criterion for being gay, just as sexual activity is not a criterion for being heterosexual (for example, children, young adults, and celibate adults can be gay or heterosexual, even though they have never been sexual).
4. Based on the Kinsey study, you state that there are 2.5 million people in the U.S. who are exclusively homosexual. The excellent report of the Committee on HIV Research* correctly noted that the Kinsey study is over 40 years old. It was produced during the very homophobic McCarthy era, when fewer gay people were exclusively homosexual.

*"U.S. General Population Projected AIDS Mortality Rate," *Report of the Committee on HIV Research.* Schaumburg, Ill.: Society of Actuaries, July 1989.

This figure is much higher now, and most sociologists contend gay men and lesbians compose about 10 percent of the population. The total homosexual population is estimated at 10 times the 2.5 million figure on page 314. Thus, the 2.5 million figure could be described as "gay men who are at high risk for AIDS."

5. Just as one should not study female prostitutes to understand heterosexual women, one should not generalize to gay men in general the results of a study of gay men with AIDS. On page 319, do not mislead the reader into assuming that the average gay man in 1980 had unprotected receptive anal sex with 130 different people per year. Assuming that there are five times as many gay men as assumed, then the average number of sexual contacts is accurate for only one-fifth of the gay male community—those called "high-risk gay men."
6. Psychiatrists and sociologists contend that one reason gay men are sexual with multiple partners is because of society's negative reaction to permanent (and thus visible) gay relationships. Changing attitudes of society then could affect the behavior of gay men in a way that would reduce risks of HIV infection to everyone. Actuaries can play an important part in improving society's reaction to gay relationships by suggesting domestic partners benefits for gay couples.
7. Psychiatrists and sociologists also contend that some gay men have dangerous unprotected activities due to low self-esteem caused by society's placement of low value on a gay man's life. For example:

   A Dallas judge gave a very light sentence to a murderer because "he only killed a homosexual." (The judge has been censured by a state panel of his fellow judges.)

   A young gay man was drowned in Maine by a gang of men and the town acted negatively towards his friends who wanted to hold a remembrance service for him.

   Thus, education toward eliminating societal prejudices towards gay people could contribute to reducing HIV infection by allowing gays to value and protect their own lives.

   Just as insurers get involved in the issues of workplace safety and abuse of cigarettes, alcohol, and other drugs in order to reduce their risks, they have become concerned about alleviating the problems discussed in items 6 and 7.
8. Plumley used the preferred word "blacks" instead of "negroes." Many people also prefer that the words "gay men" be used instead of

"homosexuals." The words "gay men" are also more precise because lesbians rarely get AIDS.

9. You mention the "unfortunate" circumstance of a monogamous married partner getting infected by transfusion (on page 288). I think you probably agree that any AIDS infection is unfortunate.
10. According to the recent Report of the Committee on HIV Research, progression rates to AIDS from the Cowell-Hoskins study of older SFCC/CDC data and Frankfurt data are slightly high. The more recent Committee Report predicts still slower progression rates in the future. This is especially true due to the successful use of AZT (and newer drugs) for HIV+ people. Page 348 discusses the sensitivity of the results to the progression rate. I guess this is partially due to the methods used (that is, slower progression means more people were infected in the past).
11. On page 300, the cumulative death rate is increased beyond 90 percent (at time $t = 5$ years) to 100 percent (at $t = 10$) for people with AIDS. Actual CDC statistics have only gone as high as 90 percent. See Table H-3 of the report of the Committee on HIV Research. This is an important point to someone who has AIDS.
12. Due to the effectiveness of AZT for HIV+ people, many gay men are getting tested for HIV now. Thus, the "knowledge factors" in Table 15 for gay men are increasing rapidly.
13. It was extremely important for public policy that the steep decline in new infections in the gay male community be emphasized in both the text and the chart on page 323. As Plumley points out, this decline is due to intensive education in the gay community. Studies have shown the most effective education was:
    (1) Literature stating that anal intercourse is "not cool"
    (2) The effects of knowing friends who have died
    (3) Literature on using condoms and water-based lubricants.
    The data suggest that education is the most cost-effective means of combatting AIDS, as well as the most humane. This is probably why concerned insurance companies have found it economically wise to spend millions on AIDS education as well as on therapies for Persons with AIDS (PWA's).

I appreciate being able to comment on the paper, and again, I want to reiterate that it was a very good, thoughtful paper with intriguing numerical projections.

BEDA CHAN:

I congratulate Mr. Plumley on a very illustrative paper for modeling the epidemic by analyzing scenarios of behavior.

I would like to point out that since the completion of the paper, there are several estimates of a longer progression time from HIV+ to AIDS. In an update of the SFCC study [2, Appendix G], Hessol et al. estimate a median progression time of 10.1 years. In [1], it is reported that subjects can be infected but remain seronegative for up to three years; the degree of infectiousness during such periods is unknown.

As pointed out by Mr. Plumley, a slower progression rate will result in a larger estimate of HIV infections and larger number of AIDS cases. As indicated in the paper, an increase in the median progression time from 7.2 years to 8.6 years (Table 1, Frankfurt to SFSS/CDC) would lead to an increase of about 40 percent in new AIDS cases (Table 28). The increase of progression time as indicated by [1] and [2] would be of the same order of magnitude. It would be of interest to apply Mr. Plumley's model to these new data.

REFERENCES

1. IMAGAWA, D.T. ET AL. "Human Immunodeficiency Virus Type 1 Infection in Homosexual Men Who Remain Seronegative for Prolonged Periods," *New England Journal of Medicine* 360 (1989): 1458–62.
2. "U.S. General Population Projected AIDS Mortality Rates," *Report of the Committee on HIV Research*. Schaumburg, Ill.: Society of Actuaries, June 1989.

COLIN M. RAMSAY:

I would like to congratulate Mr. Plumley on his excellent paper. His treatment of this sensitive topic deserves a great deal of credit.

Plumley's paper clearly reveals the complexities inherent in modeling the AIDS epidemic. There are numerous factors to take into account, three of the most important ones being socioeconomic class, city size (metropolitan, urban, rural, and so on) and geographic area (Northeast, Midwest, and the like). However, because of the lack of reliable data, he did not take these factors into account.

However, Mr. Plumley introduced an important issue: the impact of HIV/AIDS on the black and hispanic communities. Recent statistics have shown that blacks and hispanics have a disproportionately high percentage of the number of AIDS cases reported to the Centers for Disease Control [1]. While blacks are roughly 12 percent of the population and hispanics are 7 percent,

they represent 27 percent and 15 percent of the reported AIDS cases, respectively. In general, blacks and hispanics also have a disproportionately high percentage of the sexually transmitted diseases [4].

There are marked differences in the patterns of the spread of HIV among blacks and hispanics as compared to those among whites. The prevalent mode of transmission of HIV among whites is through homosexual or bisexual contact, while among blacks and hispanics it is mainly through IV drug use or heterosexual contact. There is also significant transmission through homosexual/bisexual contact [1]. However, the risk of HIV infection is a direct result of behavior and *not* an inherent feature of race [5].

With the minority population growing at a faster rate than the white population, the minorities will eventually become the majority. In the meantime, an ever-increasing proportion of the work force will belong to the current minority population. With their generally inferior access to good health care [2], their cost of insurance can be expected to rise at a faster rate than that of whites. As a result, it may be more expensive for employers to provide insurance benefits to minorities. The resulting social consequences of such a state of affairs may be staggering. The AIDS epidemic will drive up insurance costs for everyone [3].

I would like to take this opportunity to call on the Society of Actuaries to initiate a task force to investigate the impact of these changing (minority) demographics on the future costs and availability of insurance.

REFERENCES

1. CENTERS FOR DISEASE CONTROL. "HIV/AIDS Surveillance Report." Atlanta, Ga., August 1989.
2. GEMSON, D.H., ELINSON, J. AND MESSERI, P. "Differences in Physician Prevention Practice Patterns for White and Minority Patients," *Journal of Community Health* 13 (Spring 1988): 53–64.
3. HOLLAND, D.M. "Observations on the HIV Epidemic and Managing Uncertainty in Insurance," *Insurance: Mathematics and Economics* 8 (1989): 211–32.
4. MORAN, J.S. ET AL. "The Impact of Sexually Transmitted Diseases on Minority Populations," *Public Health Reports*, 104 (November-December 1989): 560–65.
5. SELIK, R.M., CASTRO, K.G. AND PAPPAIOANOU, M. "Racial/Ethnic Differences in the Risk of AIDS in the United States," *American Journal of Public Health* 78 (December 1988): 1539–45.

(AUTHOR'S REVIEW OF DISCUSSION)

PETER W. PLUMLEY:

First, I sincerely thank the discussants for their kind words about the paper. It is always gratifying to receive praise from one's peers regarding an endeavor as extensive as this. I particularly thank Mr. Fuhrer, who pointed out several typographical errors in the formulas that had occurred in typesetting as well as a theoretical error (which fortunately made very little difference in the numerical results) in the formulas for heterosexuals.

Before responding to several of the points made by the discussants, I have a general comment. The purpose of the paper was twofold. First, it presented a mathematical process for projecting the AIDS epidemic. Second, it used this process to project the epidemic based on data available through September 30, 1988.

The process of approval and eventual publication of papers is lengthy. For most papers, this does not unduly detract from the timeliness of the material. However, projections of the AIDS epidemic should be based on up-to-date data, if at all possible, because of the constant availability of new information. In this respect, the *Transactions* is ill-suited as a vehicle for publication of numerical projections of the epidemic. It is my hope that my techniques for projecting the epidemic will be used with more up-to-date information to develop more accurate projections of the epidemic than were possible from the data available at the time I did my work.

Mr. Cowell compares my projections of AIDS cases with those of the CDC and with those of Cowell and Hoskins and indicates that his represent a closer fit to the CDC's. However, the CDC figures (at least through 1989) are cases actually reported, whereas mine are based on date of diagnosis and therefore include an allowance for cases diagnosed but not yet reported. Such cases can amount to a significant number. A comparison of Tables 6 and 7 of my paper shows that there were an estimated 34,000 as of September 30, 1988. Presumably this number is increasing as the number of reported AIDS cases increases. When this adjustment is taken into account, the differences in the projections become much smaller.

Mr. Cowell's comments about the racial differences are well taken. I did not have reliable data on racial differences, and I did not want to detract from the paper by making subjective assumptions that might have been attacked as being racist. For example, I used the same behavioral assumptions for all races, even though there might well be significant differences

by race. If better data become available, it might be well to do projections with more variations by race.

Commenting on my statement that a major decrease in HIV infections among heterosexuals could be achieved by "merely avoiding sexual activity with those in high-risk groups," Mr. Cowell discusses the lack of knowledge by many of their HIV positive status. However, knowledge of one's own HIV status has nothing to do with avoidance of sexual activity with those in high-risk groups.

Mr. Cowell also is critical of my use of the word "only" when commenting on the small percentage of heterosexuals who are HIV+. My statement was made within the context of contrasting the proportion of heterosexuals infected with the much larger proportions of homosexuals and IV drug users who are infected. Within the context of my statement, I believe the word "only" to be appropriate.

In criticizing the use of "only," Mr. Cowell refers to 200,000 AIDS deaths within the heterosexual population and compares it with the deaths of 350,000 people annually from smoking, claiming that both could be avoided by "adhering to healthy lifestyle practices." These statements are wrong on two counts.

First, nowhere in my paper do I suggest that there will ever be 200,000 deaths annually from AIDS among heterosexuals. In fact, Table 15 shows that even as far in the future as the year 2000 the annual number of AIDS cases among heterosexuals will be just over 15,000. Even this number is, in my judgment, very pessimistic, in that it assumes that ten years from now, in spite of all the medical research currently under way, some of which already is demonstrating some success, there still will not be any technology available to slow or stop the progression from HIV+ to AIDS.

Second, his reference to "healthy lifestyle practices" apparently assumes that the spread of heterosexually transmitted AIDS is caused by sexual activity with someone other than one's primary sexual partner. This ignores the implications of the low efficiency of transmission of the AIDS virus. These implications are discussed in the paper and illustrated in part in Tables 35 and 36. In contrast to the homosexual situation, the number of sexual partners makes very little difference in the risk of HIV infection for heterosexuals. However, the nature of one's sexual partner makes a big difference. A substantial majority of heterosexually transmitted AIDS cases are blacks or hispanics who allegedly became infected from sexual relations with IV

drug users. The low efficiency of transmission suggests that in many, perhaps most, of these cases the IV drug user was the primary sexual partner of the person becoming infected.

It is for this reason that heterosexual AIDS education efforts regarding avoidance of multiple sexual partners and emphasis on the use of condoms probably are destined not only to fail, but also to cost lives in the process. Studies have indicated that these warnings may be ignored by those who really need to listen—the young blacks and hispanics involved with persons in the drug scene and by those with a primary sexual relationship with an infected partner.

On the other hand, they are likely to be heard by the white, middle class, more socially conscious people, who make up the majority of the population and who will then be sufficiently terrorized that they will shrink from developing relationships to the extent of doing harm to their opportunities for a rewarding life. A rewarding relationship, including a good sex life, can be a major factor in promoting a healthy lifestyle and consequently in reducing mortality and morbidity rates. Thus, for these people, the cost in terms of human mortality and morbidity (and human happiness) may well be far in excess of the very small risk that they would incur from AIDS if AIDS warnings were ignored.

I am particularly disturbed by Mr. Cowell's quote from Robert May's work. A great effort has been made to teach the public that AIDS does not spread by casual contact. Even so, many people are still fearful of any contact with persons with AIDS, and much injustice has resulted. We should not be promoting the idea that AIDS spreads by casual contact any more than we should be emphasizing that one can be killed by a plane crash while asleep in one's bedroom. Although both might be theoretically possible in an unusual situation, both involve risks that are so slight that those who understand risk levels would consider them to be unworthy of consideration. Unfortunately, most people can understand that the risk of the plane crash is insignificant, whereas when it comes to AIDS, many people tend to look at transmission of the AIDS virus as either "possible" or "impossible," and they panic when told that it is "possible" no matter how unlikely the possibility is.

Mr. Fuhrer discusses the use of mathematical techniques in AIDS modeling. Although he may be correct in his analysis (I readily admit that he is a better theoretical mathematician than I am), my belief is that his approach would make it more difficult to allow for such matters as behavioral changes,

undercounting in the early years, and changes in the definition of AIDS.

Mr. Gebhardtsbauer's comments largely relate to the paper's treatment of male homosexuals. I have two disagreements with him.

First, he claims that about 10 percent of the population is homosexual (either male or female). Although the homosexual community has tried to convince others that the actual number approximates this in order to maximize its political clout, it is my understanding that the percentage of male homosexuals (meaning those who are sexually attracted to men and not women, and excluding bisexuals, who are attracted to both sexes) actually is much lower, probably 4 percent or less of the male population.

Second, he suggests that I should use "gay" instead of "(male) homosexual" because I use "black" instead of "negro." The CDC uses "black" and "male homosexual" in its reports on AIDS, and I believe those are the correct terms to use at present.

Again, I would like to thank the discussants for their valuable comments and for their compliments.