ects Agency of the Department of Defense through Contract No. DAHC 15-68-C-0119, and wish to thank the Department of Defense for providing this useful compilation of the literature. We have also reviewed the commentary on the Midwest Research Institute report by a committee appointed by the National Academy of Sciences (transmitted by letter of 31 January 1968 from the president of the National Academy of Sciences to the director of Defense Research and Engineering) and the comments of a number of individual scientists whose judgments concerning this report we requested.

Our review of these documents leaves us with the conviction that many questions concerning the long-range ecological influences of chemical herbicides remain unanswered. The extent of long-term deleterious effects of the forest defoliation in Vietnam is one of these unanswered questions (1, 2)*. We do agree that the use of arsenicals on crops may have serious hazards, and we are concerned with the ultimate route taken by arsenical compounds in plants, soil, and animals. Therefore, on the basis of the information available to us, we do not share the confidence expressed by the Department of Defense (in the letter of 29 September 1967 quoted above) that seriously adverse consequences will not occur as a result of the use of herbicidal chemicals in Vietnam, insofar as arsenical compounds are concerned.

In the course of our study, we became aware of the serious concern expressed by scientists in Vietnam over long-term environmental consequences of the military use of herbicides. Extensive claims of environmental poisoning through use of these agents have been made. Because of uncertainties in available evidence on the long-term effects of such materials, such charges cannot now be answered unequivocally.

Because large-scale employment of herbicides has taken place in Vietnam, and because questions of the long-term welfare of all the people of Vietnam are of great importance to the United States and other countries, we urge that steps be promptly undertaken to initiate detailed, long-term, on-the-spot studies of the regions of Vietnam affected by the use of herbicides. If rehabilitation of lands adversely affected by these agents is required, ecological studies initiated now will be of substantial value in defining the required programs. If defoliation has produced or can produce beneficial influences on the food-producing capacity of the affected regions, these possibilities should be evaluated fully so that they can be most effectively exploited for the benefit of the Vietnamese people.

Accordingly, we urge that a field study be undertaken under the auspices and direction of the United Nations (3), with the participation of Vietnamese scientists and scientists from other countries, and with cooperation, support, and protection provided by the contending forces in the area. This study, which could well be supplemented by experimental work elsewhere, should provide a detailed environmental analysis of the long-range effects of the agents used and of the steps necessary to assure optimum future productivity of the environment for the welfare of its inhabitants.

Further, we urge that the maximum possible amount of relevant data be released from military security, so that the scientists conducting the study may know the areas affected, the agents used, the dates applied, and the dosages employed.

We express especial concern about the use of arsenical herbicides in Vietnam, and urge that their use be suspended, if it has not already been stopped, until the ultimate fate of the degraded arsenical compounds can be more reliably determined.

We recognize the difficulties involved in the proposed field study; however, it is our hope that the feasibility of such a study may be increased as a result of the current peace talks in Paris.

Finally, we hope the recommended study can be initiated promptly and we proffer the good offices of the Association in helping to plan it and to publicize its findings.

DON K. PRICE, *Retiring President and Chairman, Board of Directors*
WALTER ORR ROBERTS, *President*
H. BENTLEY GLASS, *President-Elect*
PAUL E. KLOPSTEG, *Treasurer*
BARRY COMMONER, HUDSON HOAGLAND
GERALD HOLTON, MINA S. REES
LEONARD M. RIESER, H. B STEINBACH
KENNETH V. THIMANN, DAEL WOLFLE

Supplementary Statements by Some Members of the Board of Directors

1) The confidence of the Department of Defense that seriously adverse consequences will not occur as a result of the dissemination of herbicides by military operations in Vietnam is unwarranted, we believe, not only with respect to arsenical materials, but also with respect to 2,4-D and 2,4,5-T. According to the Midwest Research Institute report, the latter are being sprayed in Vietnam at dosage levels about ten times greater than the levels used in domestic applications. Therefore the estimates regarding possible long-term effects that are derived from domestic experience are not applicable in Vietnam. Since, to our knowledge, there are no relevant observations in Vietnam itself, it is not possible at this time to make a reasonably accurate prediction of the long-term effects of dissemination of 2,4-D and 2,4,5-T. However, there are specific reasons to anticipate certain important hazards from the use of these herbicides in Vietnam. According to the MRI report (pages 198–200), 2,4-D inhibits the formation of nitrogen-fixing nodules in leguminous plants; plants of this type are particularly important in tropical vegetation. In addition, according to the MRI report (pages 201–203), 2,4-D and related herbicides induce serious chromosomal abnormalities in various higher plants by interfering with the mitotic apparatus that governs the behavior of chromosomes during cell division. Evidence advanced by the MRI report that these herbicides do not cause mutations in bacteria is irrelevant since bacteria lack the chomosomal apparatus which is affected by the herbicides. Hence, intensive use of 2,4-D and 2,4,5-T in Vietnam may cause widespread chromosomal damage among plants, with effects —on the genetic characteristics of the affected plants and therefore on their ecological behavior—that cannot be foreseen at this time. For these reasons, we believe that the scientific grounds for the use of herbicidal chemical weapons in Vietnam—that is, Department of Defense confidence in the judgment that they will cause no long-term effects—are not valid. Accordingly, in keeping with the precept stated in the Department's letter of 29 September 1967, the herbicide program should be stopped. Apart from the morality of the war itself, which is not at issue here, continued used of a weapon with effects

* Supplementary statements, indicated by numbers, appear at the end of this statement.

that are so poorly understood raises serious moral and political questions for the U.S. government and for the American people. These ought to be carefully considered in the present national debate on the morality and political wisdom of the war in Vietnam.

BARRY COMMONER, GERALD HOLTON
H. BURR STEINBACH

2) We consider that the use of 2,4-D and 2,4,5-T for defoliation of forest cover probably represents a military device for saving lives that has an unprecedented degree of harmlessness to the environment. We consider that the material in the Midwest Research Institute report in general supports this view.—WALTER ORR ROBERTS, KENNETH V. THIMANN

3) We do not agree that the Board of Directors should recommend that the United Nations assume responsibility directly for making the proposed study. While we would agree that the U.S. government should propose that the United Nations sponsor the study, we believe that in case such a course of action is not politically feasible for the United Nations, the U.S. government should reserve the option of initiating and supporting such a study through some private institution or special panel of independent observers.

H. BENTLEY GLASS
HUDSON HOAGLAND, GERALD HOLTON
PAUL E. KLOPSTEG, DON K. PRICE
MINA S. REES, LEONARD M. RIESER
WALTER ORR ROBERTS
H. BURR STEINBACH, DAEL WOLFLE

Herbicides in the Perspectives of 20 Months and 20 Years

The wartime plutonium production project had a fantastic safety record. So does the ever-expanding U.S. peacetime power reactor program. Neither came about by accident. There was concern at the top. It was reflected in the concerned collaboration of competent colleagues. Their experience stretched from the safe manufacture of ammonia under unprecedentedly high pressure to the safe manufacture of high explosives, from biology to meteorology, and from safety against sabotage to sanitary engineering. I am a nuclear physicist. I was privileged to work with these able men from 1942 to 1953. In addition to other responsibilities I had this double duty: First, to dream up every conceivable way in which trouble might come about, however fantastic; and second, to make order-of-magnitude calculations of the size of the effect to be expected—and of the means to protect against it. Out of this personal experience* come three working principles relevant to the use of herbicides:

First, every significant pathway by which a contaminant—or a perturbation—can make its way from A to B must be part of the bookkeeping before one can chalk up the final safety balance. Second, one need not know the flow in every pathway to have the information needed for safe action. Instead it is enough to consider for each imaginable situation the "worst case," make the appropriate order-of-magnitude calculation, and take safety measures accordingly ("upper limits" versus "actual values"; "margin of safety" approach). Third, as subsequent research reveals more about individual pathways, safety margins undergo further improvement, or economy of operation rises, or both.

From going through the Midwest Research Institute Report and the careful reviews of that report by the National Academy Committee and others qualified in the field, and from considerable additional discussions, I am led to conclude that

1) We know enough today to set a variety of useful upper limits.

2) Twenty more months of research will not produce an order-of-magnitude increase in the available information.

3) The information on hand is a guide to policy and can be summarized so succinctly, and—what is more—put into perspective that any final report to AAAS members will be deficient if it does not undertake this task. A few facts and figures may be given as examples, focused on acres, pounds, and pounds per acre (Table 1).

Certain additional elementary items of information and "worst cases" are significant for perspective. For example (a) 2,4-D, long familiar as the leading herbicide and still a leader, is being overtaken by other herbicides which, however, do not have radically different properties. As an addendum to the Board statement implies, the use of herbicides for defoliation is a device of unprecedented harmlessness for saving allied lives. (b) Quite different from 2,4-D is arsenic containing cacodylic acid (dimethyl arsenic acid). For a time it found favor as a leaf remover. Now it is being dropped gradually for the same reason that arsenical sprays are being given up in tobacco land: The arsenic slowly accumulates and in years can become a liability to animal health. For

Table 1.

Area of first 48 states	2000×10^6 acres
Wooded United States	638×10^6 acres
Commercial forest industries	67×10^6 acres
Herbicide-sprayed farmland, United States, 1959	53×10^6 acres
Sprayed farmland, 1965	120×10^6 acres
Rightaway: Power, phones, roads, railroads	26×10^6 acres
Mesquite-affected range in Southwest	70×10^6 acres
Sprayed range in Southwest	3×10^6 acres
Area of Rhode Island	0.8×10^6 acres
D.M.Z. in South Vietnam, 6 miles by 50 miles (sprayed)	0.2×10^6 acres
Cropland in South Vietnam sprayed to deny crops to Viet Cong	About 0.2×10^6 acres
Cultivated land in South Vietnam not so sprayed	8×10^6 acres
S.U.N. forest defoliated per year to permit inspection	About 1×10^6 acres
Total forests of Indo-China	77×10^6 acres
Use of 2,4-D ("Weedone") or 2,4,5-T or mix	
To improve grazing in forest for deer and rabbits	1 lb./acre
To kill undersirable hardwoods, preserve pines	4 lb./acre
To kill brush, save pine seedlings	8 lb./acre
To control knapweed on range	100 lb./acre
To remove leaves for 4 months from jungle canopy	5 to 30 lb./acre
To start conversion of jungle to grazing or cultivatable land	5 to 30 lb./acre
1966 U.S. use of 2,4-D	57×10^6 lb.
U.S. annual production capacity of 2,4-D	80×10^6 lb.
Estimated needs for 2,4-D in Southeast Asia per year	80×10^6 lb.
Total U.S. production of herbicides per year	300×10^6 lb.

* A distinct report because written by a Board Member with a distinct background.