argue, particularly in the face of a suggestion by Hutt that they carried the burden of proof to show that no hazard existed. Rigorous adoption of such a principle would make much research hard to justify. Hutt seemed later to modify this position when he said that, since scientists had taken the initiative in raising the safety issues, they should be allowed to keep it.

But he warned that they might lose the initiative if they failed to take certain additional steps. One omission was public participation. "I do not believe that the public's rights should be affected by guidelines drawn up by any group which has not undergone the procedures for public participation laid down in the administrative procedure act," Hutt said.

Another loophole in the guidelines is that they do not address the question of proliferation. Although analysis of a recombinant DNA experiment requires expensive equipment, the simple construction of the molecules probably is or will be within the capability of a high school laboratory. But the guidelines are at present enforceable only by denial of NIH funds, and would not apply to industry, foundations, schools, and other laboratories. Congress, in Hutt's view, is unlikely to let such an anomaly exist. It could be abolished, he suggested, by exercise of an obscure law in the Public Health Service Act which gives the Surgeon General sweeping powers to control communicable diseases.

The hearing has left Fredrickson with a decision that is both technical and political in nature. Because almost all research with the technique has been embargoed, not much new has emerged to add to the technical arguments. There is still no clear answer to such elementary questions as whether bacteria such as *E. coli* can synthesize the protein products specified by the genes of higher organisms. If they cannot, the risk of inserting such genes into bacteria is obviously much reduced. In political terms, the hearing seemed to underline how hard it is for those with a direct interest in the experiments to make a fair case for themselves. Several speakers, for example, criticized the guidelines for allowing shotgun experiments with insects, referring indirectly to an experiment now under way in Hogness' laboratory. Possibly too little attention was paid to a technique developed by Hogness and a colleague which removes much of the objectionable random element in a shotgun experiment.

A chief lesson of the hearing was thus that the rationales behind the guidelines, the reasons for pressing ahead with the experiments in face of an irreducible minimum of risk, need to be spelled out in terms that are persuasive to Congress and the public. Up to now, that argument has only been made to other scientists, who have an intellectual interest in the results. Fredrickson's second problem, if he considers it within his ambit, will be to suggest ways for controlling the technique on a national basis. Here again, discussion hitherto has focused on practice in the best laboratories. The real problem is how to maintain control over the technique when it gets into the hands of the worst.

—NICHOLAS WADE

Pest Control: NAS Panel Warns of Possible Technological Breakdown

The U.S. government will, over the next decade, be looking increasingly to the high productivity and abundance of American agriculture as a major source of national economic and political strength in a world in which food may be in desperately short supply. Yet a National Academy of Sciences (NAS) study committee is now warning that future agricultural productivity is threatened by a possible breakdown in chemical control of pests.

In a five-volume report released 5 February, the NAS committee,* which was chaired by Donald Kennedy, a professor of biology at Stanford University, pointed to three developments that are "challenging" the effectiveness of chemical technology.

- Genetic resistance has appeared in many "target" insect pests. Since the discovery 25 years ago of resistance to DDT in the housefly, some 200 other insect species have been found to exhibit genetic resistance to chemical pesticides. In fact, "most of the major pests" affecting agriculture and public health have been found resistant to some chemicals, at least over part of their geographic range.
- "Natural" pest control mechanisms are often disrupted, as when beneficial insects as well as target pests are killed by a chemical compound toxic to a broad spectrum of insect life. In California's San Joaquin Valley, for example, the organophosphate insecticide used by cotton growers to prevent outbreaks of *Lygus*, a plant-sucking bug prevalent throughout the growing season, also kills certain predators which normally control the bollworm, a late-season pest. Moreover, predacious insects seem not to develop genetic resistance to chemical insecticides as readily as do target pests.
- Use and development of chemical pesticides is increasingly constrained by laws and regulations adopted in the interest of environmental protection and occupational health and safety. Several important chlorinated hydrocarbon pesticides, including DDT and aldrin and dieldrin, have been banned already, as have certain mercurial fungicides. Still other commonly employed chemicals, including arsenicals, certain phenoxy herbicides, and the rest of the chlorinated hydrocarbon pesticides, could in time be either banned or severely restricted in their use. Furthermore, development of new pesticides is made more difficult and expensive by the new regulatory regime. Although not decrying the new laws and regulations, the report says that they must be taken into account, and perhaps modified in certain particulars, in the shaping of alternative pest control strategies.

According to the report, successful alternative strategies will require further use and development of such approaches and technologies as the following:

1) Breeding pest-resistant plants and introducing genetically modified pests, such as sterile males, into natural populations.

2) Developing bacterial and viral agents to which farm pests will be vulnerable—a control technology already showing "great promise." †

3) Developing "third-generation" chem-

* Others besides Kennedy on the Executive Committee responsible for the study were Perry L. Adkisson, entomologist, Texas A & M University; Samuel R. Aldrich, Agricultural Experiment Station, University of Illinois, Urbana; Donald L. Dahlsten, entomologist, University of California, Berkeley; John E. Davies, epidemiologist, University of Miami School of Medicine; Boysie E. Day, plant physiologist, University of California, Berkeley; Carl Gotsch, Harvard University; James E. Krier, professor of law, University of California, Los Angeles; Michael C. Latham, nutritionist, Cornell University; Matthew S. Meselson, biochemist, Harvard University; William W. Murdoch, biologist, University of California, Santa Barbara; Kusum Nair, visiting researcher at East-West Food Institute, Hawaii; Charles E. Palm, professor of agricultural sciences, Cornell University; Vernon W. Ruttan, Agricultural Development Council, New York; and Roy A. Young, vice president for research and graduate studies, Oregon State University.

icals designed to interfere specifically with the biochemical systems of target pests while having little if any effect on vertebrates and other nontarget organisms.

4) Employing ecologically-based, integrated control strategies which, besides perhaps taking advantage of some or all of the above, will involve adoption of various "cultural practices" (such as adjusting planting and harvesting schedules) designed to prevent outbreaks of particular pests.

In connection with these recommendations, the report calls for better application of contemporary theory in population biology and ecosystem analysis to pest control problems.

The report recommends that the U.S. Department of Agriculture (USDA) and the state agricultural experiment stations support and encourage greater use and development of such theory. It then points to the "heavily concentrated structure of the agricultural research enterprise," and calls for the National Science Foundation and other agencies responsible for the support of basic sciences to encourage "the increased use in basic research of organisms and ecosystems that may yield benefits to the science of pest control." It also recommends that the USDA and other agencies with a pest control mission be given the resources to make "competitive extramural grants for basic research to qualified investigators wherever they are located."

One conclusion reached by the NAS committee which is sure to displease part of the agricultural research and pest control communities has to do with efforts at the total eradication of certain pests, such as that old and formidable enemy of cotton growers, the boll weevil. In the committee's opinion, eradication programs are well advised only under the most favorable circumstances, as when the target pest is confined to a relatively small region.

The boll weevil is found throughout the original "cotton belt" stretching from Virginia to Texas, and it occurs also in Mexico, the place from which it first invaded the United States in the 1890's. A proposed belt-wide project to eradicate the boll weevil (*Science*, 8 February 1974) could easily cost $1 billion or more, yet offer no assurance of success. A particular concern of the NAS committee was that, in the event that such a campaign failed, the public might lose confidence in the alternative control strategies employed rather than place the blame where it belonged—on the eradication concept itself.

The report invites the inference that the NAS panel agreed with many criticisms that have been made in the past as to the quality and direction of the work of the federal-state agricultural research establishment. But, by and large, it maintains a positive thrust by pointing to new opportunities rather than to past inadequacies. At this writing, few research administrators at USDA have had an opportunity to review the report.

Jacqueline Warren, a Washington attorney with the Environmental Defense Fund who has taken part in the series of law suits and administrative proceedings to ban several of the chlorinated hydrocarbon pesticides, is pleased with the report. She notes its emphasis on the need for new integrated pest control strategies as an alternative to conventional strategies relying heavily on chemical compounds. She also notes with satisfaction the report's endorsement of the Environmental Protection Agency (EPA) practice of using animal test data to determine whether a pesticide is a potential carcinogen in humans which must be banned or restricted in use.

Pesticide manufacturers and the USDA have disputed the validity of some actual or proposed pesticide registration actions based on such data. But the NAS committee says that "despite the problems involved in translating the results from [animal] experiments to human risk, the present techniques are sufficiently reliable to justify registration actions based upon such data alone, on an interim basis, until evidence convincingly demonstrates that there is no human risk." It says, too, that more money should go into the gathering and analysis of epidemiological data bearing on human exposure to pesticides and the incidence of cancer and other diseases.

The report also observes that, while a billion pounds of toxic pest control compounds are placed in the environment each year, "it is 'normal' for us to have only the vaguest idea of how much of each compound was used and where, and then only after a half a decade's lag." It calls for this situation to be remedied through an improved system of reporting by USDA and EPA. In addition, it recommends better reporting of the occupational injuries suffered by farm workers as the result of pest control activities.

The NAS study leading to the report began in August of 1972 under the auspices of the Academy's Environmental Studies Board. Besides the executive committee headed by Kennedy, four other study panels were created, one for pest control and public health and others for pest control in forestry and in the cultivation of cotton and of corn and soybeans. Each panel produced a separate report. Altogether, the study involved the work of about 60 scientists and other specialists and the expenditure of about $300,000, of which the Ford Foundation provided half, with USDA and EPA providing the remainder.

With one or two exceptions, the main thrust of previous NAS reports on pest control and pesticides has been in support of the status quo. Quite clearly, the present report cannot be so characterized, and its influence may be the greater because, while its authors were mindful of human health and environmental problems, their study focused on the effectiveness of present and future pest control strategies and technologies.—LUTHER J. CARTER

† In January, the Environmental Protection Agency registered, for the first time ever, a pesticide made from a naturally occurring insect virus; this product, bearing the trade name Elcar, has been approved for use against two highly destructive cotton pests, the cotton bollworm and the tobacco budworm. Other viruses are now being tested for the control of two timber defoliating insects, the gypsy moth and the tussock moth. Also, a fungus that is the natural enemy of a weed common to rice fields is being tested in Arkansas, and a protozoan known as *Nosema locustae* is being tested in Montana and Wyoming for control of grasshoppers.

RECENT DEATHS

Oscar L. Alm, 88; professor emeritus of psychology, Kansas State University; 18 November.

Joseph W. Barker, 84; former dean of engineering, Columbia University; 10 December.

Nathan Birnbaum, 68; professor emeritus of chemistry, City College of New York; 9 December.

Walker E. Bryan, 90; former professor of agriculture, University of Arizona; 26 November.

Victor L. Butterfield, 71; president emeritus, Wesleyan University; 19 November.

Richard H. Chamberlain, 60; former chairman of radiology, University of Pennsylvania; 5 December.

Philip Cox, 92; professor emeritus of education, New York University; 5 December.

Theodosius Dobzhansky, 75; adjunct professor of genetics, University of California; 18 December.

Gustav Hertz, 88; nuclear physicist and Nobel Prize winner; 30 October.

Frank P. Jones, 70; professor emeritus of classics, Tufts University; 15 October.

William T. Mac Creadie, 87; former associate professor of mathematics, Bucknell University; 13 November.

James M. McDonnell, 56; associate professor of biology, West Chester State College; 8 December.

W. Byers Unger, 77; former professor of zoology, Dartmouth College; 2 November.

Aleksandr A. Vishnevsky, 69; head, Institute of Surgery, Soviet Academy of Medical Sciences; 19 November.

E. Grace White, 85; former chairman of biology, Wilson College; 1 December.