the Senate Assembly and one student elected by the Student Government Council. If all of the persons specified above concur that the proposal is in full compliance with the provisions of these policies, it will be regarded as cleared for administrative processing and funding.

c. If any of the persons specified above (i.e., Dean or Director, Vice President, faculty member, or student) believes that there is a substantial question as to the proposal's compliance with any of these policies, the proposal shall be referred to the Committee on Research Policies for review. Their evaluation as to compliance shall be transmitted in writing to the Vice President for Research prior to acceptance or rejection of the proposal for signature and forwarding of the sponsor.

While the Vietnam war obviously forced the issue, changes in federal-university relations have not been brought about simply by activist attitudes. A. Geoffrey Norman, vice president for research at Michigan since 1964 and a member of the Michigan faculty since 1952, has been in a prime position to observe the process.

After World War II, scientists and engineers were drawn into military research at most major universities. At Michigan, it started in the engineering college, says Norman, and widening sponsorship "soon made it clear that the engineering college was not the place to administer it."

The Michigan Aeronautical Research Center was established at Willow Run (the name change came in the 1950's) and did the sort of thing that resulted in its being chosen to share the work and the acronym with Boeing in producing the BOMARC study for an integrated air defense system against bombers. For a considerable time, says Norman, "the work came in the form of big contracts allowing considerable latitude for us to do what we were interested in. It was a very desirable kind of federal-university relationship permitting university researchers to examine new areas of technology." To a degree, says Norman, university researchers "became science advisers to the agencies. Until the mid-1960's, this pattern prevailed."

Since then, "a different attitude has developed in the agencies" of the Department of Defense (DOD), says Norman. And this change is reflected in the requirement of much more specific work statements. Behind it is the Mansfield Amendment, which for a time required that research commissioned by DOD agencies have a direct relation to the agency's mission. "The Mansfield amendment, I would say, had a very subtle and damaging effect.

A Message from Corn Blight:

"And he gave it for his opinion, that whoever could make two ears of corn or two blades of grass to grow upon a spot of ground where only one grew before, would deserve better of mankind, and do more essential service to his country than the whole race of politicians put together." Swift's prescription in *Gulliver's Travels* for earning a nation's gratitude has been amply fulfilled by the plant geneticists and others through whose efforts the crop production per acre in the United States has doubled over the last 40 years. But this triumph contains the seed of a potential disaster. Crops have tended to become genetically more uniform, rendering them vulnerable on an epidemic scale to new pathogens. A foretaste of what could happen was the epidemic of corn leaf blight in 1970, which devastated 15 percent of the crop. The blight, a new mutant strain, attacked only a single type of corn, but that type was grown by almost every farmer in the country.

The blight was brought under control the following year by favorable weather and the return to a resistant type of corn. It prompted concern about the extent to which other essential crops had become genetically uniform and vulnerable to epidemics. The question has been addressed in a report published this month by the National Research Council (NRC) of the National Academy of Sciences and prepared by its Committee on the Genetic Vulnerability of Major Crops.* The committee's answer is that "most major crops are impressively uniform and impressively vulnerable."

This somber warning is based on a review of the genetic history of the major crops and an analysis of the economic and legislative pressures that encourage uniformity. Many of the technological advances in crop production depend on small numbers of genes. Prominent examples are the dwarf varieties of wheat and rice that comprise much of the base for what has been called the Green Revolution. The danger is that, if one of these genes is incorporated into many varieties and a parasite with a preference for the characters controlled by that gene were then to come along, the stage would be set for an epidemic. Uniformity resting on a single character was responsible for the epidemic of corn leaf blight. The same kind of uniformity has been introduced into commercial varieties of sorghum, millet, sugar beet, and onion. The trend toward uniformity is also evident in the handful of major varieties that account for the bulk of many crops. For example, two types of pea and nine varieties of peanut comprise 95 percent or more of their respective crops in the United States.

How did things get that way? Uniform crops are easier to sow, easier to harvest, and easier to market. The farmer's demand for high-yield varieties drives out the lower yield varieties, which also makes for uniformity. Since crop uniformity is what society demands, that is what the scientist provides, "knowing full well that one day his uniform variety may suffer in the face of an epidemic," the NRC report states. The irony is that, when an epidemic does occur, the scientist, not the forces of the market, tends to receive the blame.

In the case of the 1970 corn blight, the uniformity lay in the single source of cytoplasm, known as Texas male-sterile cytoplasm, which had been used by breeders in developing the majority of the corn hybrids planted that year. The Texas cytoplasm hybrids had been extensively tested for resistance to the corn blight fungus and found to perform as well as plants with normal cytoplasm. True, the fungus was known to attack the Texas cytoplasm plants in the Philippines, but this was ascribed to the Philippine weather, not the nature of the parasite. In any case, past breeding experience indicated that the cytoplasm was not a factor that was likely to be important in disease resistance. In the light of hindsight, it may have been a mistake to convert so much of the

* *Genetic Vulnerability of Major Crops.* Obtainable from the Printing and Publishing Office, National Academy of Sciences, 2101 Consitution Ave., NW, Washington, D.C. 20418; $7.50.

It started people thinking too much about military applications." Citing pioneering work done on holography at Willow Run, he observed that researchers "did not start looking for technological applications, spinoffs. The Mansfield Amendment inverted this. The kind of work we've been doing for the past 5 years has been less and less suitable for graduate student participation, courses in engineering. All of this has been a change and made us ready for a different kind of operation here."

(Defense research funding has declined steadily at Michigan since the 1968–69 academic year when defense agencies provided about $14 million or 22 percent of the $62.1 million research budget for the university. For 1971–72 tentative figures show that the amount from DOD sponsors was down to $7.3 million or around 11 percent of the total budget. In a total research budget of $62.2 million in 1970–71 federal funds amounted to about $45 million with the $17.2 million provided by the Department of Health, Education, and Welfare representing the largest amount from a single sponsor.)

Norman acknowledges that, as U.S. involvement in the Vietnam war increased, defense agencies laid greater stress on "weapons end-item development" but insists that the university's role was limited to "demonstrating the feasibility of applications." Defense agencies turned to military contractors for subsequent steps.

Norman, who himself has been a target of criticism in the debate over classified research, feels that the effort to rewrite the research guidelines "did not make them much more precise." He believes that "the committee got to the point of prejudging what was in the mind of the sponsors." Part of the trouble, he says, is that the sponsors were using military language rather than scientific language. "There's a jargon," says Norman, just as there is in the health field, indicating that applications for biomedical research grants often stress rather optimistically the implications for health care in the research in question.

As for Willow Run, says Norman, from the university's standpoint "we realized that for the health of the enterprise, separation was necessary." He suggests that separation was also in the national interest, since "these activities would probably not thrive if they remained here."

"The separation from the university

The Dangers of Uniformity

commerical corn to a single source of cytoplasm, the NRC committee states. But there are no villians to uncover, only a "system where unseen forces carry well-meaning scientists toward a problem they had not intended or foreseen."

Could a similar epidemic threaten rice, a crop that feeds half the world's population? The high-yield dwarf strains developed at the International Rice Research Institute have now been introduced into almost all the countries of tropical Asia. Is there a danger that all of the dwarf varieties may succumb to some disease or insect simply because all have the same dwarfing gene? The consensus of opinion is that they will not. But the introduction of the dwarf rice is reducing genetic diversity by replacing traditional varieties. The high-yielding dwarfs also seem to be more prone to certain disease organisms and insects, whose multiplication is favored by the increasing use of fertilizer and the luxuriant growth that results. "Other things being equal, the danger of serious crop losses from the attacks of major diseases is greater today than in the past," the NRC committee considers.

Wheat is another major crop whose natural variability is being eroded by the widespread introduction of new strains. Rapid acceptance by farmers and the popularity of a few varieties has led to near monoculture in some regions of the world. The high-yield, semidwarf wheats from Mexico have caused notable increases in wheat production in many countries. But there is a potential danger in having a single genetic type gain such widespread popularity. Very little is known about the genetic interaction between wheat and its numerous parasites. As a result, the NRC committee warns, "We have the frightening probability that wheat is genetically vulnerable to damage by disease."

Epidemics of the past have sometimes been tragic in their consequences. Ceylon, the leading coffee nation of the world in 1870, was unable to export a single bag by 1885 after an attack of coffee rust disease—and the British became a nation of tea drinkers. Three successive epidemics ravaged the French wine industry in the latter part of the last century. Banana wilt struck throughout the Caribbean at the turn of the century, wiping out one variety of bananas and ruining many plantations. The Bengal rice crop was devastated by a fungus in 1942 and tens of thousands died of hunger.

If uniformity is the crux of genetic vulnerability, then diversity is the best insurance aganst it. The procedures used by most plant breeders tend to narrow rather than expand the genetic base of cultivated plants, in part because proven, elite germ plasms are easier to work with than untested ones. Plant breeders, says the NRC committee, should provide diversity, including back-up systems when things go wrong. In the epidemic of corn leaf blight, the breeders had a highly effective back-up system in the form of replacing the Texas cytoplasm with normal cytoplasm. To maintain a base for genetic diversity, gene pools need to be developed for major crops, particularly those in whose area of origin the primitive varieties and wild types are being threatened by the import of "improved" varieties. For wheat in particular, the erosion of centers of natural diversity is proceeding at an alarming rate.

The NRC committee recommends that a "watchdog system" be set up to study crop pests abroad that could be a major threat if introduced into the United States. A national monitoring committee should be established to assess the development and production of major crops and to watch for potential hazards. The committee, to be composed of scientists from all interested constituencies, should be advisory in nature but free to issue warnings whenever it feels them justified. The NRC committee itself warns clearly that the methods and technology of production in the United States and elsewhere are increasing the probability of major crop epidemics.—NICHOLAS WADE