As a result, an evaluation of biotech's applications in the military must include not only its potential benefits, but also its ability to combat the new biotechnological threat.

The predominant military uses for biotechnology fall into four categories: biomedical, biodetection, decontamination, and materials biotechnology. What follows is a discussion of the research the military is conducting in each of these categories.

Medical Biotechnology

Medical applications of biotechnology focus on diagnostics and vaccines designed to protect the individual from the hazards of biological and chemical agents. Diagnostic methods include the monitoring and detection in body fluids of viruses, drugs, and toxic compounds.

The military's vaccine program consists of the genetic engineering of vaccines active against malaria, hepatitis A, dysentery, and meningitis, among others. The program also includes developing polyvalent vaccines against viral diseases of potential biological warfare importance. The intent is to protect the battlefield soldier from exotic bacteria and parasites, or at least to provide partial protection so he can sustain himself before obtaining medical treatment. While private-sector research centers around the more common vaccines against polio, diphtheria, and typhoid, the military focuses on rarer diseases that pose a threat to the soldier on foreign soil.

Where vaccines cannot be developed, medical efforts focus on the design of drug and toxin therapy and prophylaxis. The program includes immunoregulators, antivirals, and antitoxins. Though in early stages of development, drug therapy offers a fast, effective, and more economic treatment against—as well as protection from—toxic agents. In the long term, applied medical biotechnology can help design products to provide rapid wound repair, organ and tissue regeneration, nerve cell repair, artificial blood, and protection from radiation and other battlefield threats.

Bio-Detectors, Receptors, Probes

Recently, new avenues in detection technology have opened, especially in the area of biological detectors and bioprobes. Biodetectors combine chemical and biological materials with microelectronics and industrial process engineering. New applications for molecular sensors in medicine—such as diagnosis, drug delivery, and patient monitoring—continue to proliferate. Biodetectors are fast becoming private industry's technology of choice. They are being engineered to monitor toxic pollutants in the environment and contaminants in industrial processes. Military applications are aimed at detecting chemical and biological warfare agents—including pathogens and toxins—with greater specificity, selectivity, sensitivity, and speed than otherwise available with conventional sensors.

Among the biological detectors under development, biosensors seem the most promising (see Figure 1). These sensors consist of two components: a molecular recognition element, which can be a chemical, an antibody, or an enzyme; and a transducing signal-generating component that converts the reaction into an electrical or optical signal. Measuring chemical and biological substances usually entails a complex procedure often with sophisticated equipment, e.g. gas chromatography or mass spectrometry. Biosensors, on the other hand, are faster and cheaper. A dipstick assay based on an immunological reaction, for example, forms a simple and disposable biosensor. Coated with an antibody specific for a chemical or biological substance, the dipstick causes the reaction solution in which it is immersed to change color in the presence of the target agent. (The Army is working with Soman—a nerve agent—as its target, while other countries are exploring other target agents.)

More sophisticated immunosensors currently are being developed as well. Of these, fiber-optic sensors seem most promising. Here, a transducing element consisting of optic fibers is coupled with light of distinct wavelengths. By coating the fibers with various antibodies, a fiber-optic sensor can measure several compounds simultaneously. Although specific and selective, immunosensors unfortunately are slow. Moreover, the antibody-antigen complex does not lend itself readily to superimposition on the transducing element. (One solution to slow-reacting immunosensors would be to use catalytic antibodies, which act as enzymes and catalyze the reaction much faster. Furthermore, they also help reduce interference and background noise.)

An alternative technique for producing a fast-reacting biosensor uses an enzyme as the molecular recognition element. Although stable under laboratory conditions, enzymes—which are sensitive to temperature perturbations as well as other environmental extremes—cannot be applied easily under field conditions. To function properly, they need to be immobilized and stabilized. Artificial enzymes, still in early stages of development, are one possibility under examination. Another approach uses enzymes isolated from thermophilic bacteria. They are able to work at extremely elevated temperatures—a characteristic that contributes to their stability in extreme environments. As enzymes and antibodies do not function well under field conditions, efforts are underway to use entire cells and tissue sections (which as yet cannot be coupled as efficiently to a signal-generating element). Researchers hope to overcome the stability problem and, at the same time, encompass a variety of molecular recognition properties in one and the same system.

The military's biodetection efforts are focused on receptor-based biosensors. The advantages of receptors are numerous: They can bind several agents at the same time in seconds,

---

A CONGRESSIONAL MANDATE FOR MILITARY RESEARCH

In March 1989, in response to a congressional mandate, the Departments of Defense and Energy designated 22 technologies as critical to national security and the long-term superiority of weapons systems. The parameters for selection included: an ability to significantly enhance particular weapons systems; an ability to create new capabilities or systems; improved systems reliability and maintainability; and affordability.

Thirteen of the 22 categories related to computers, communications, or radar and other target-sensing technologies. Another four related directly to the improvement of weapons systems, two to the development of particular new materials (including superconductors), and two to the study of aerodynamic properties. The last category—biotechnology materials and processing—was the only one other than superconductivity research which designated the broad-based utilization of a new technology in as-yet unspecified ways. —**Mark Ratner**
