Abstract- The major advances have been made in the life sciences in recent years. New research in the life sciences, using the techniques of biology, biochemistry, and biophysics, has resulted in a new field called biotechnology. Biotechnology research endeavours have the potential of solving many of the military operational problems faced by the Army which, as a land combat force, has its personnel and equipment exposed to a wide range of natural and enemy generated environments. Moreover, much of the Army's Biotechnology research so far has gone into the development or improvement of vaccines, diagnostic tools and possible defences against biological or chemical warfare agents. Current nonmedical Biotechnology exploratory research efforts are in the development of new materials such as adhesives and lubricants, light weight armor, composites, non-polluting cleaners, degreasers and ultrasensitive sensors. Decontaminants and coatings, improved rations, fuel and water production, navigation systems and biomemories for high speed computers and robotics are further areas amenable to Biotechnology applications.

Keywords- Biotechnology, vaccines, biosensors, rations, water production, robotics.

I. INTRODUCTION

Biotechnology offers solutions to Army needs, not specifically related to battlefield environments. Among these needs are improved energy sources and new materials for military applications. Some of the ways biotechnology may be exploited for Army needs are in the production of high performance fibers having both high tensile strength and energy absorption; Lighter and lower cost ceramics for use in armor, radomes, and electronics; Ultrasensitive sensors for detecting chemical and biological agents; control of manufacturing processes and in environmental protection, Self assembling biomaterials for use in electronic components such as high current density cathodes; reactive materials for rapid and effective degradation of chemical and biological agents; soldier rations optimized for specific climates and missions; reactive materials and coatings capable of providing protection against directed energy radiation, or capable of mimicking local natural signatures to provide camouflage protection. The Army's approach in biotechnology research and development is multifaceted. Most of the Army's fifty million dollars per year biotechnology investment is focused on medical applications, while more modest investments are being made in areas such as synthesis of fibers, biological sensors, ordnance enhancements, and production of safe decontaminants.

II. APPLICATIONS OF BIOTECHNOLOGY IN ARMY

- Medical Field

Common medical practices have already greatly benefitted from biotechnology discoveries and applications. Vaccines [2] and prosthetics among many others have been significantly improved and
diagnostic tools and mass production of vital substances, such as insulin, have become available for the first time. Biotechnology offers new approaches for coping with Army medical needs as well. Enhanced protection against biological warfare agents, infectious diseases, and combat casualty (i.e., septic shock) are a few areas of possible benefit. Artificial blood for combat casualty treatment and long-term storage and supply needs could be developed. Biomimetic systems could also be developed as replacements for blood, as oxygen recovery systems from water, or as organ/bone replacements or implants. The potential impacts of biotechnology on medical needs for the Army are presented in table 1.

- combat casualty care- wound repair, organ regeneration, nerve cell repair, and artificial blood
- prophylaxis- protection from radiation and biological and chemical agent
  - immune system enhancement
- diagnostic- monitoring and detection in body fluids using biosensors
  - molecular probes
- drug and toxin therapy- immunoregulatory, anti-viral compounds, antitoxin drugs
- Vaccines to parasites, bacterial, and viral diseases.

III. TECHNICAL CONCEPTS AND BIOTECHNOLOGICAL SOLUTIONS TOWARDS ARMY

The potential impact of biotechnology on operational and logistical needs of the Army in various technical areas is outlined in the following pages. Many materials necessary for operations could be improved and/or more easily produced through the application of biotechnology, making facilities more operationally self-sufficient and cost efficient. Some of the technical concepts discussed include specific results anticipated from the applications of biotechnology. These are presented by defining a current problem and outlining biotechnology solutions.

A. BIOSENSORS

Current Problems

The chemical and biological threat is becoming more complex, and an expanded threat detection capability is required to maintain or improve our operational capabilities. Currently fielded detection systems can only detect approximately 50% of the known chemical threats. Systems under development (e.g., portable gas chromatograph /mass spectrometer and laser detectors) are expected to work against all known chemical threats, but are still limited with respect to future chemical threats. In addition, these detection systems are complex, with the associated reliability problems and high cost. The capability to detect all biological and chemical agent threats, multiple agent threats, and future bioengineered threats would provide improvements over our current capabilities. In addition, detection of industrial activities through environmental monitoring could provide early strategic information for improved readiness and arms control monitoring.

Biotechnology Solutions

Biosensors, based on the direct combination of a matrix-bound bioactive substance (the receptor) with an electronic device for signal transduction, are able to recognize and analyze biological and chemical agents, providing the requisite speed and accurate detection capabilities for battlefield use. Biosensors combine the recognition capability of biological receptors with the transduction and amplification of micro sensors, providing wide spectrum detector capabilities for toxins, chemical agents, and pathogens. As neuroreceptors, ion channels, antibodies, and other natural biological recognition sites are isolated and purified, and in a few instances cloned and produced, the possibility of engineering recognition sites for specific threat agents draws closer. Biosensor researchers are currently attempting to reconstitute or artificially mimic membrane bound reception channels for use as specific, ultra-low level analytic devices. However, the production and stabilization of receptor proteins have been major technological bottlenecks. Additional issues, such as the coupling of the biological
component to a transducer, the device that converts power from one system for use in another, must also be addressed.

B. Chemical and Biological Defense  
Current Problem  
Current protective systems for the Army cannot provide protection from all acknowledged chemical and biological threats. For individual protection, protective clothing systems provide absorption of chemical agent threats using charcoal. Protective overboots and gloves, as well as impermeable shells for chemical protection are fabricated from butyl rubber. This material is heavy, retains heat, and is subject to penetration by petroleum, oil and lubricants, thereby compromising its chemical/biological protective performance. The current charcoal based protection systems are result in heat stress to the wearer, severely degrading a soldiers Performance; present potential out-gassing problems because the agents are absorbed and not destroyed; and are not reusable because they can become saturated and lose effectiveness, and must be disposed of after one use. Future biological threats may increase significantly with the advent of genetic engineering, and new chemical and toxin threats will continue to appear [4]. Protective systems must mitigate all of these future threats whether delivered as vapor, liquid, or aerosol. Therefore, there is a need to develop generic protection systems capable of degrading chemical and biological agent threats. Current decontamination chemicals (e.g., STB, DS2) exhibit broad-based activity against biological and chemical agents but are highly caustic. These chemicals damage materials and pose handling, storage, and contamination problems to equipment, handlers and the environment. Further, the decontamination chemicals cannot be used on electronic or computer equipment, thus adding to logistics burdens, and presenting environmental concerns. Improved active protection from all biological and chemical agent threats, without the negative impact of heat stress, would improve the performance of the individual soldier. Similarly, decontamination compounds that are mild and can work under ambient conditions would vastly improve the decontamination of sensitive equipment such as electronics, microcomputers and internal components, as well as improve logistics and handling procedures.

Biotechnology Solutions  
Reactive materials, such as biochemical catalysts, which include enzymes, peptides, enzyme active sites, catalytic antibodies and biomimetic systems offer the potential for rapid and effective degradation of chemical and biological agents under ambient conditions. Some of these reactive macromolecules can provide active protection against generic classes of chemical and biological agents, including both current and future bioengineered threats. In addition, these macromolecules could be immobilized or carried in a variety of matrices to perform their function. For example, the catalyst systems would be active against agents carried in aerosol, liquid, or vapor media and could be immobilized on fabrics or used in solutions, salves, or detergents. They may be reusable and could eliminate out-gassing concerns because the agents would be destroyed and not just immobilized or trapped. Further, they would not be susceptible to saturation because of the high catalytic turnover rates. Developing multi-functional reactive coatings and finishes to provide integrated protection against both biological and chemical agents would be a major achievement.

Rations for Soldier Performance Optimization  
1. FOOD  
Current Problems  
Current military rations are designed to meet generic minimum daily requirements for micro- and macro-nutrients. Performance of mental and physical tasks shows a time-dependent decrease with either current or improved field rations when they are used as the sole food source for periods of two weeks or more. The rations are generally designed to meet the caloric and nutrient requirements for
standardized human performance. They will generally provide adequate sustenance for about fourteen days before continued human performance can no longer be guaranteed. However, they are not optimized for specific combat/environmental stress scenarios, including arctic or desert battlefield stress differences, encapsulation, confinement in small spaces, or for sustainment of continuous operations. The development of novel systems for the conversion of inedible substrates or alternative food sources to nutritional materials in survival scenarios, and the improvement of nutritional quality or stability of foods are also needed.

**Biotechnology Solutions**

Improved nutrition, storage stability, and new opportunities for nutritional supplementation/performance enhancement are possible through the application of biotechnology to food science. Generally, improvements envisioned include encapsulation for slow release of critical nutrients, carriers, or digestion aids; enzyme modified ingredients for better digestibility aid energy availability; and new anti-oxidants for improved and safer long-term storage stability. Optimized rations can also be used during training to improve capability and performance. Edible packaging materials could also help in solving waste problems.

Bioengineered rations optimized for performance in specific battlefield or environmental stress scenarios can provide the necessary nutritional content to enhance performance or minimize performance degradation. For example, enzymatically modified fats to enhance digestibility, modified amino acids to promote alertness, controlled release, and ration components that target specific organs would all provide enhanced operational performance through bioengineered rations. Some specific nutritional strategies that can be considered include increased fat digestion and absorption with natural surfactants such as special lecithin, which also contain choline for possible memory enhancement.

Controlled and sustained release of carbohydrates by adding special polysaccharides, may serve a dual function as soluble dietary fibres and sustained energy sources. Special peptides or proteins rich in neurotransmitter precursor amino acids, such as tyrosine, serve as a reservoir for sustained delivery of antistress nutrients, and liposome and sustained release encapsulation systems provide controlled delivery of high impact nutrients. Enzymatic synthesis or modification of the compounds described above, fermentation and bioprocessing for the production of these compounds, encapsulation of specific labile components, modifications in food microstructure, and targeting techniques are biotechnology examples of the tailoring of rations for performance optimization.

2. **WATER**

Water is always a mission critical resource. The lack of available water supplies in many areas, the lack of potable water, and weight penalties for carrying water all push the need to develop novel methods for soldiers to produce water in the field as needed. Improved capability to generate, recover and purify water would enhance operational performance in most environments. Current Army bulk water purification systems rely on reverse osmosis membranes, except for the individual soldier, where charcoal-based purification is utilized. The soldier's charcoal-based water purification system cannot be used for desalination. Developing a single membrane for all applications, providing enhanced flow rates for faster processing, more efficient processing of water to reduce energy requirements, stable to environmental variables, and storable in wet or dry conditions would be the ideal solution and may be reached through advanced biotechnology. Some microorganisms survive in highly saline environments and are capable of generating osmotic gradients across membranes. The gradient systems used by these microorganisms could be exploited to develop new approaches to water purification and recovery. Some biopolymers, as opposed to current synthetic polymers, have greater stability, higher flow rates, and are non-reactive with disinfectants. They can therefore be formed into improved membranes for developing these types of gradient osmosis systems. Novel, enzymatically-driven water producing reactions could
also be exploited. Self-organizing membrane structures with selective reactivity and rapid through-put are envisioned. Genetic probes could be developed for rapid detection of pathogens potentially contaminating drinking water. In addition, anti-freeze proteins and glycoproteins could be used to prevent freezing of water in colder climates without requiring energy input. An example of this type of anti-freeze technology, found in nature, has been observed in certain fish and mammals living in the arctic and may be adapted when more fully understood.

C. ROBOTICS

Robotic systems are being developed as replacements for humans in situations such as loading ammunition in tanks, as mobile surveillance platforms to detect and identify troop movements, and in intelligent maintenance, diagnosis and repair systems. These systems require advanced data retrieval and processing and sensor abilities. They must also be durable in hazardous situations and reliable especially when used for assays or quality control. Robotic systems provide a "natural" application of biosensors for the sensing of chemical agents, detection of hazardous materials or explosives. If biosensors for navigation are achieved they could be applied to autonomous robots as well. The engineering of artificial sense organs will require studies of photoactivated pigments for optical sensors, pressure transducers for proprioception, olfactory receptors, and other novel sensory systems capable of utilizing abilities found in natural organisms. Military robots will require many of the same novel synthetic materials as commercial robots. However, bioceramics, biopolymers and bioplastics more suited for hazardous military missions or for enhanced performance capabilities may be required.

IV. CONCLUSION

Potential adversaries are highly likely to take advantage of developments in biotechnology to achieve dubious ends. As such, the Army must position itself to monitor the expanding fields of biotechnology, to influence developments supportive of future applications, and to exploit new opportunities as they appear. The overall goal of Army biotechnology endeavours is to improve operational capabilities and solve logistical problems. By employing protein and genetic engineering techniques of biotechnology, it is anticipated that significant advances can be achieved in a wide spectrum of materials, processes and systems.

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