CHAPTER 6

Biotechnology

The field of biotechnology presents new opportunities and dangers in the realm of national security. Biotechnology is essentially technology meant to augment our control over life, and possibly someday even death. The application of the life sciences is not a new thing—agriculture and medicine have several millennium of history. What sets apart the biotechnology being speculated on today is its potential for rapid and precise control over a growing number of biological processes. The promise of biotechnology has the potential to reshape the lives of individuals, their descendants, and civilization wholesale.

Military biotechnology reinforces the primacy of people at the core of military affairs. It is for human needs that wars and politics by less-drastic means are conducted. With strong artificial intelligence either in the far future or simply an impossibility, human intelligence will still be calling the shots in the near term and probably the medium term as well. Warfare is not an antiseptic video game, and the consequences of war are suffered by people—the traumas suffered by the warfighter, those caught in between, as well as those back at home. Even while other emerging technologies may be increasing the distances at which the enemy may be engaged, the effective use of military force cannot overlook the human warfighter.

Biotechnology, even without military applications, is a controversial technological area. For many, biology and medicine are unsettling fields due to the visceral nature of the subject. The life sciences in general involve wet and seemingly unpredictable things. Many see advance biotech as simply an exercise in hubris, with technological control over life at the degree promised unobtainable. Others question whether humanity can be trusted with such power over life itself—something that historically has been regarded as the

Thanks to many past and ongoing high-profile cases of unintended medical and agricultural side effects, there are those who doubt that there will be true mastery over biology. Nature has repeatedly thrown up unexpected challenges when a medical breakthrough seemed within reach. Possible unintended side effects of militarized biotechnology range from simple personal injury, all the way up to extinction-causing epidemics. Some forms of genetic treatment and modification affect reproductive cells, meaning that these changes would be passed on to any children conceived after the genetic adjustments took hold. With society becoming increasingly risk adverse there are some areas of biotech that society may decide are simply not worth pursuing.

There are of course elements of civil society that would automatically label militarized use of any technology unwise. Some find specific cause for concern in biotechnology's potential to infringe on individual free will and human dignity. Past experiences with nations attempting to improve humanity have led to all manner of nightmarish policies from institutionalized discrimination, to wholesale murder. Noted defense and international relations scholar Martin van Creveld wryly comment that many of the technologies discussed in this chapter would be applicable to the elimination of war—via the end of individual freedom:

> A completely automated thought-reading machine—for nothing less would do—would have to be hooked up with the human brain and capable of influencing it by chemical or electrical means. Robots would have to control men, men themselves turned into robots. We find ourselves caught in a cross between Huxley's *Brave New World* and Orwell's *1984*. So monstrous is the vision as to make even war look like a blessing.[1]

Some in the field of medical ethics are troubled about the use of medical knowledge to improve the effectiveness of weapons. Although there is probably not much angst found in the research and development needed to produce a logistically more convenient field ration, there is great debate over using an increasing understanding of human biology to make a more effective kill mechanism. Somewhere in between is the application of life-sciences knowledge to less-than-lethal weapons. At its core are philosophical questions over what constitutes harm, and how such high ideals mix in with real-world practicalities of national security.

Another sign of tension between scientific ethics and practical security was the recent debate over U.S. government's attempts to prevent open publication of research on the H5N1 virus, specifically how it can be intentionally modified to be more easily transmittable.[2] Legitimate science requires free and open publication; however, with advance biotechnology

Arguably in this case, it seems the needs of national security led to a more cautious stance and the high ideals of science are perhaps the more reckless position.

The convergence of biotechnology with other emerging technologies such as nanotechnology and advance computing is leading to a future that will be hard to predict. Although some futurists are happy to paint visions of a future of longer life and better health, others are not so sure. Old threats such as biological weapons will have in the emerging technologies new avenues for development and deployment. As these very same technologies are providing countermeasures, it is unclear if biotech and other emerging technologies will lead to a more or less secure world. By definition, the technological singularity that some have predicted as the ultimate result from the convergence of today's emerging technologies is a point where the future will become impossible to predict due to an accelerated pace of technological development and scientific discovery. That a technological singularity is not the only possible outcome from the emerging technologies only adds to the uncertainly.

That there will be convergence of these areas is the only certainty. Nanotechnology exits at a scale that overlaps with biological constructions such as components of living cells. This means that nanotechnology is a possible means to directly adjust the function of living creatures down to the level of cells. Rudimental linkages between electronics and the human nervous system have already been implanted. Even without direct implantation, there are continuous developments in the area of noninvasive human-machine interfaces borne out of research into how the people can make use of hard technology—and how such technology changes how people work, play, and even fight. Biotechnology on the other hand is being harnessed to produce nanoscale products and may in future allow for computers to continue shrinking beyond barriers to conventional integrated circuit fabrication. Even the more specifically military- and aerospace-related emerging technologies have their links to biotech. Directed energy weapons converge with biology in the form of understanding how various forms of directed energy may disrupt parts of the body, such as the nervous system, to produce less-than-lethal effects. In the event that space access were to become a ubiquitous military capability, organizations such as the United States Marine Corp have already started to look again at the requirements for prompt global troop deployment via suborbital spaceflight[4]—where among the challenges would be life support. Technology-enhanced soldiers, although not unique to the space deployment concept,[5] would be a critical requirement simply due to the logistical costs involved. Overall it is perhaps the training and support improvements borne out by biotechnology that will provide the most military utility.

Biotech: The Familiar, the Mundane, the Prelude to Unsettling Things?

Biology is fundamentally chemistry, and chemistry at its most basic level is physics. The function of every molecule critical to life, deoxyribonucleic acid (DNA), proteins, hormones, neurotransmitters, and the adenosine triphosphate that powers cells all can be understood in terms of hard physics. Now living cells are complex systems, but with the convergence of biotechnology with computer technology much of the computational burden of unlocking life's secrets has become manageable. The completion of the Human Genome Project in only 13 years[6] was only possible with the exponential growth of computer technology.[7] As mentioned in the previous chapter, the scale of nanotechnology and fundamental biological processes are often one in the same. This means that nanotechnology provides potential tools for probing and manipulating biological processes. With enough understanding, it is expected that technology can be devised to both monitor and to tinker with any bodily function in a precise and controlled manner—this is the promise of biotechnology.[8]

Among the promised advances borne out of applying molecular chemistry to biology are improved drug-delivery systems. Analysis of the cellular structures has revealed a host of identifiable molecular-scale characteristics that may be used as markers for identifying cells for diagnostic and treatment purposes. Medical equivalents to smart bombs may be developed that use specific molecular markers as both "guidance" and triggers.[9] Only in the presence of targeted cells would a drug activate, meaning that other cells would be left alone. This is of particular interest as a means of delivering cancer-fighting drugs only to targeted cells. By targeting specific cells, such as those in a tumor, healthy cells are not exposed mitigating the side effects of the treatment attacking healthy cells. In general, this approach can be applied to many biological functions to produce drugs with reduced side effects.

Borrowing again from the military lexicon would be various biotechnologies that aim to camouflage drug molecules from the body's defenses. Large doses of many drugs have to be applied, again with possible side effects, due to the body naturally breaking down or outright attacking the treatment itself. There are also parts of the body that have natural barriers, such as the blood-brain barrier, that have limited the options for pharmaceutical treatment by simply being inaccessible to most drugs. Just as stealth and precision-guided weapons have proven to be force multipliers for the United States, the combination of targeted drugs with more survivable drugs, in the face of the body's defenses will allow for old medical strategies to make use of smaller dosages with less collateral damage, as well as opening new possibilities for medicine.

Finally there is the prospect of using technology to engineer biological processes to behave in ways not intended by nature. This is the transition from basic science, the understanding of how nature works, to controlling it for use in medical and even industrial procedures. Regenerative medicine is just such an example with a direct link to military use. Defense Advanced Research Projects Agency (DARPA)[10] and other military agencies[11] are funding research into various methods tissues, organs, and perhaps even limbs that can be coaxed into regenerating. Along similar lines, and possibly of nearer term fruition, is blood pharming, the in vitro (out of body) growing of red blood cells to ease the many supply challenges faced by battlefield medics.[12] Biotechnology goes beyond improving military medical care. The aging population of the West is clearly a market for products that maintain and improve quality of life. Futurists go as far as predicting that biotechnology will be able to first understand and control the processes that limit lifespan.

Improved emergency medicine and long-term care for veterans are not only expected, but should also be demanded, as part of how any sensible society chooses to treat its protectors. This still leaves the question of what else the military will to do with the opportunities made available by biotechnology. In the near term much of what is being researched by DARPA, the perennial target of commentators looking for scary new military technologies, and other military research organizations falls under the mundane, the routine activities that together make up the necessary foundations of a modern 21st-century military. These activities range from programs to develop better training regimes,[13] augmentation of a soldier's ability to absorb information in the midst of a battlefield,[14] and exoskeletons to assist with logistical tasks.[15] Essentially, biotechnology will start off as a force multiplier in carrying out familiar and somewhat mundane tasks. However, as the military does have a reputation, indeed an institutional responsibility to find new weapons, some are fearful that what starts off as better medicine will turn into something much more terrifying.

Keeping the Soldier Going: Metabolic Sustainment and Dominance

Food is an enduring defense biotechnology product from well before the time when the term technology was in use. Though some would argue against labeling military field rations as food, the ability to keep soldiers, sailors, and air crew nourished and in good health is ultimately the key factor to a nation's ability to field persistent global influence. Research by Royal Navy surgeon James Lind led to a nutritional solution, lemon or lime juice,[16] to the problem of scurvy in long-duration sea deployments—contributing to the Royal Navy's success at sea in the 19th century. The amount of time a U.S. nuclear

submarine can remain underwater is constrained to a large degree by the amount of food that can be packed aboard. Perhaps underscoring both the rise of the private military contractor, and the ancient link between food and morale, is the phenomenon of finding U.S. fast food chains setting up shop in the middle of U.S. bases in Afghanistan and Iraq.

The need for a more compact, transportable, and easily consumed ration has been accelerated by combat experience. Research into how soldiers repackaged the meal, ready-to-eat (MRE), which initially entered service at the end of the Cold War, found that much of the nutritional content of each MRE was discarded as infantry prepared to leave base.[17] Throwing away part of the standard MRE for easier carriage was both wasteful, MREs are expensive, and unhealthy as the discarded food is needed to both fuel the body during high-intensity activities such as combat operations and also to aid in its recovery afterward. This research led to the development of the First Strike Ration© (FSR™) which is 50 percent smaller in volume and weight compared to the MRE,[18] but still contains a minimum of calories and other nutrients needed for combat operations.[19] This ration is under continual development to fit in additional dietary supplements, and expand the menu.

Beyond basic nutrition is the military equivalent to the sports drinks used to enhance athletic performance, and the energy drinks used by students to help with concentration and mental activity. Prolonged physical exertion will over time start destroying muscle tissue and damaging other organs. Added with stress of combat, it becomes clear why extended combat operations have a debilitating effect on soldiers.[20] Many of the compounds now being introduced into combat rations are meant to counteract tissue damage, quicken recovery times, and boost the immune system in response to combat stresses.[21] The term nutraceutical has come into use to describe the combination of food with medicine. DARPA as part of its 50th-year anniversary highlighted its own involvement in the development of these nutraceuticals that are beginning to appear in soldiers rations.[22] Another term for foods that do more than fulfill nutrients requirements is "functional food." The umbrella term used by the Department of Defense for these additives is performance-optimizing ration components (PORC). Indeed many of the items already being used to fortify foods or are under consideration for future inclusion, such as caffeine, vitamins, antioxidants,[23] and probiotics,[24] are things highlighted in the marketing for dietary supplements and energy foods. According to U.S. government numbers, 75 percent of the U.S. population takes dietary supplements[25] forming a market worth over $20 billion dollars a year.[26] The combination of people seeking longer and healthier lives, along with recreational and competitive athletes looking for a (legal) advantage is fueling growth in this area of biotech.

Requirements specific to military logistics (long-term storage without refrigeration, delivery to warzones) mean that military labs, such as those of the US Army Natick Soldier Research, Development & Engineering Center, are also active participants in food developments. Specific operational environments and needs have driven the development of meal, cold weather and the food packet, long-range patrol (MCW/LRP), as well as foods that seem to sacrifice resembling food to fit adequate nutrition into the most compact form possible for use in survival rations found. Additionally, unlike health food fads, the effects of specific food components have to be proven along with effective dosages before they can become a procurement item. One such study, out of Canada, linked specific dosages of caffeine with performance metrics of several infantry duties, including marksmanship.[27] Of note is that the study introduced caffeine directly to the bloodstream via chewing gum that released caffeine for absorption by the chewer's gums.

A potential biotechnology product expected in the long term related to nutraceuticals are edible vaccines produced in genetically engineered plants. It has been proposed that genetically modified (GM) food plants could produce specific proteins that would train the body to fight specific pathogens. Unlike traditional vaccines these proteins would not be sterilized pathogens, but just surface components of the targeted virus or bacteria,[28] enough for the body's immune system to recognize the real thing. Although much of the research is aimed at edible vaccines as a low-cost way to vaccinate people in the developing world,[29] it would also ease the logistical burden of preparing soldiers for deployment in these very same parts of the world. Global reach and persistence exposes Western military forces to many of the same challenges faced by those attempting to project humanitarian aid globally. With the trend of Western military forces being used increasingly for humanitarian interventions, edible vaccines would be a potentially low cost but very useful tool in the arsenal for soft-power missions.

Like many new technologies, or complex topics, and edible vaccines ranks highly in both categories, there is potential for backlash. In the West there is the persistent and unfounded panic over vaccinations.[30] Even the military is not immune to these fears, resulting in studies investigating such claims.[31] GM foodstuff in food aid has already faced some criticism from the developing world.[32] Now the biotech industry is not entirely blameless for this situation; scandals involving shoddy non-GM products, and missed opportunities for communicating the realities of GM food to the general public[33] have led to resistance toward GM foods and biotech in general. Miscommunications, media scaremongering, and outright ignorance of the scientific realities have been harnessed by everyone from political action groups against mainstream medicine and the biotech industries, to Islamic hardliners[34] trying to portray Western charity in a bad light.

Similar to the direct intake of caffeine into the bloodstream via the blood vessels in the mouth would be the transdermal nutrient-delivery system (TDNDS). The skin, being a very effective barrier against infection and other hazards of the world, is not meant to be an entry point for nutrients, but is permeable to various chemical and biological processes. The nicotine patch, used to help wean smokers off cigarettes, is probably the most visible application for transdermal delivery today. A long-term vision, the TDNDS hit the headlines prior to the Global War on Terror, presenting more immediate feeding R&D needs.[35] Part medical lab and part nutrient-delivery system that bypasses the digestive system, TDNDS would actively monitor a soldier's health during combat and deliver nutrients and nutraceuticals into the body via advance forms of the nicotine patch. It would theoretically react to counter the physiological effects of hunger, exhaustion, stress, and injury by varying the mix it was supplying to the bloodstream.

At the time, it was unclear if this technology was even viable,[36] though it does have potential linkages with other emerging technologies—small medical monitors that are worn, ingested, or implanted, along with the computer software needed to react to bodily needs figure highly in advance computing and nanotechnology categories. Similarly the delivery mechanisms could include microelectromechanical systems (MEMS) to release nutrients and medicinal compounds directly into the bloodstream. Protecting nutrient and drug molecules in nanotechnology shells that only release their payload once reaching a targeted part of the body is an emerging technology that can also be applied to the TDNDS concept. Research continues on noninvasive transdermal-delivery technology, some of it funded by the military, such as at MIT's Institute for Soldier Nanotechnologies.[37]

Probably not much more controversial than having soldiers absorb food through their skin is the idea of using the same technology to deliver therapeutic medicines. In addition to nicotine delivery, other medical therapies are already delivered via transdermal patches, such as painkiller, heart medication, and mood stabilizers. In the context of future infantry gear this delivery method would be used in conjunction with active health monitoring and active control—although the transdermal-delivery system is part of the uniform, and hence in contact with the application area of skin, it would only deliver medications on command by either remote control from military medics, or by built-in medical computers that will autonomously attempt to keep a soldier optimized for combat. Remote or autonomous therapeutic medical attention is expected to continue the reductions in treatment times that have increased battlefield survival rates. However, with the possibility of treatment comes the possibility of enhancement; this is where some become uneasy at the prospect of a drug-enhanced fighting force. Biotechnology is only providing the tools for these efforts to enhance soldier performance; the use of specific enhancements is a policy question, though one made possible by the state of the art in medicine.

Successive U.S. Army programs, Objective Force Warrior, Future Warrior, and the current Future Force Warrior have to varying degrees offered such health monitoring to enhance soldier performance. In its current guise, this is the warfighter physiological status monitoring (WPSM) system found in discussions on the Future Force Warrior program.[38] Many long-term plans for future soldier uniforms/personal combat vehicles (exoskeletons) feature materials that can harden on command, alternatively providing armor protection or acting as ad hoc medical devices to immobilize injured limbs and apply pressure as a tourniquet.[39] The smart materials needed for a soft uniform to convert on command into hard bullet-resistant armor or immobilize a limb only when needed are probably further in the future than automatic and remotely controlled drug delivery. Embedded sensors in soft uniform materials able to network with other medical systems are simply an application of the smart materials now entering the market. Programmable drug-delivery systems already exist in the form of various implantable insulin pumps, though this technology has logistical, survivability, and likely end-user resistance problems. For sheer practicality, noninvasive technologies such as transdermal delivery are much more likely to be adopted than subjecting certain military occupations to mandatory surgery.

Related to integrating medical monitoring and autonomous first aid systems into combat uniforms is the deployment of teleoperated surgical robots to the battlefield. The U.S. Army's Telemedicine and Advanced Technology Research Center (TATRC) and DARPA have been working on programs such as Trauma Pod, which aim to produce an unmanned, mobile operating room.[40] Although there are many challenges that remain for totally autonomous medical care, telemedicine promises to link doctors located far from the frontlines to those who need medical care. Remote-control triage care, along with the various robot programs geared toward extracting the wounded,[41] and possibly start treatment during extraction,[42] will cut down on response times, potentially increasing survivability on the battlefield.

The flip side of providing soldiers with the energy needed to endure for long periods in combat would be dealing with all the waste products generated by metabolism. An example would be the by-products and side effects of muscles operating in an inefficient anaerobic, without oxygen, mode due to working at levels that exceed the body's ability to deliver oxygen.[43] The pain felt by n body overtaxed by strenuous exercise is a warning sign that the body has been operating in this mode. Extending this envelope where the body is able to avoid anaerobic muscle operation is of interest to both the sporting and military communities—as would be methods to enhance the body's ability to deal with excess metabolic wastes and by-products of exertion. The

former would increase endurance as it would train the body to work in a more sustainable manner. The latter would increase the amount of time a body could sustain intense activities, such as sprinting, as well as shorten recovery times after periods of such activity.

Along with metabolic waste, the body also produces debilitating amounts of heat during physical exertion. Sweating is the natural coping mechanism for this, but this has side effects such as dehydration, and is not always an option as soldiers become more enclosed in protective gear. Using technology to keep soldiers cool is in some ways not much of a future capability—body temperature regulating suits have been a requirement for spacesuits since the early space age. However, much of the research linking heat, fatigue, and performance is quite recent,[44] and the goals are different: in the space program the purpose of personal climate control was to protect from the hostile environment of space; for the soldier it is sustain combat operations and increase performance by easing the load on the body's ability to regulate heat.

Many future infantry programs are including active temperature regulation as a means to increase endurance. Externally powered micro climate-control suits have been developed for pilots, and more recently for vehicle crews on patrol, to extend the amount of time for which they are effective in hot environments, such as Iraq.[45] New textiles with integrated active elements such as heat-conductive fibers and smart materials engineered to help transfer away heat are certainly options to producing less bulky and mass-deployable personal climate-control systems than those now in use for the space program.

The Mind of the Future Combatant

Though it may be a cliché, the mind is perhaps the key to enhanced performance overall. Just as the Information Age has flooded the workplace with e-mails and memos, the Information Age battlefield has its own forms of information saturation, along with e-mail and memo traffic. Concerns about information overload go beyond productivity metrics for the soldier; the ability to manage battlefield information may have an impact on personal survivability and mission success. Better-designed technology, expert systems, and forms of artificial intelligence will streamline how information is presented, but in the near and medium term it will still be the human mind that will be the limiting factor. Although one does not have to subscribe to decision-making models such as Colonel John Boyd's OODA (observe, orient, decide, act) loop, no one would desire a slower or impaired thought process. This research is now allowing biotechnology to be entering the market that promises to augment natural decision making and other thought processes, essentially technology to allow soldiers to outthink the enemy.

Caffeine can be described as a socially acceptable stimulant, and is perhaps only the tip of the iceberg, and where biotechnology starts entering the controversial territory of adjusting the state of a soldier's mind. Practical needs in the middle of combat have in past, and will continue to in future, required soldiers to remain functional for inhuman lengths of time. Training, preparation, and caffeine can only do so much and there remains a need to use controversial drugs to keep soldiers in fighting condition for lengths beyond natural human endurance. Militaries have historically turned to stronger pharmaceuticals than caffeine to push back exhaustion and keep soldiers fighting longer. This included the use of amphetamines by all sides during World War II.[46] Medical authorities in United States and other militaries still find utility in stimulants such as dextroamphetamine under very specific circumstances where sleep deprivation is unavoidable, and under medical supervision,[47] though it is noted that due to side effects, and overall cost to medical infrastructure, pharmaceutical options should not be the first choice.[48]

Although operation needs may force the use of stimulants, the risk should be appreciated. Long term, many stimulants, amphetamines, and related drugs have a potential to form addictions. In the short term side effects include behavioral and mood changes. As a neurologically active substance there is a risk of impairment to the senses and overall thinking process. It was alleged by the defense during the court martial of U.S. Air National Guard Major Harry Schmidt that side effects of command-approved "pep pills" contributed to the friendly-fire incident.[49] Used incorrectly, the impairment brought on by lack of sleep is replaced by impairment brought on by the stimulants. Additionally, overdoses can lead to death through a variety of mechanisms, and over time physiological effects may cause long-term health problems. Eventually the body will require sleep and rest to recuperate—something medication will probably never change.

The research into how the human body deteriorates between periods of rest as well as the technology to counteract such physiological and psychological breakdowns are dual use in nature. Medical research is ongoing into studying both the general nature of sleep as well as specific sleep-related disorders. Better treatments for sleep disorders are to be expected but there is also a market for over-the-counter prescription, as well as illicit energy boosters and stimulants. The popularity of energy drinks is indicative of this market, as well as its dangers. There are now concerns over the health effects of energy drinks, both in long-term consumption as well as their potential for an "overdose." The nutraceutical qualities of these products also introduce the problem of how they interact with other drugs and alcohol. Military-funded research could be useful for this market in that it provides objective standards for effectiveness, as well as a second look at safety.

Building on research into methods to fight off fatigue and the need for sleep is research into enhancing cognitive performance. Warfare in the 21st century is as much about information as it is about brute strength, which means that the more effective soldier is one able to process and react to information faster. Outside of combat, warfighters are required to master a great amount of technical information concerning equipment and operations. Although computers may be able to perform number-crunching feats such as discerning hidden patterns from the every growing intelligence databases, a human analyst will still need to put a context to what is found. These are the national security factors that have fuelled research into not only how the mind works, but also into how to improve it.

National security is not the only driver for tools to improve the mind; the civilian world in general has become more competitive, dispelling any notions of a laid-back and relaxed technological-assisted 21st century. The U.S. National Research Council 2008 report, *Emerging Cognitive Neuroscience and Related Technologies*, noted that market pressures from both an aging society and from healthy individuals seeking a competitive advantage would be a great driver in the development of cognitive neuroscience technology goods and services. The report also noted that the use of these drugs for enhancement was largely underground,[50] in that these drugs are meant as therapies for failing and abnormal cognitive abilities, attention-deficit hyperactivity disorder (ADHD) for instance, but instead are being used by healthy individuals to boost memory and ability to learn. It should be noted that many of these drugs are controlled substances and, among other side effects, are potentially addictive.[51]

The prospect of biotechnology being able to create drugs specifically to boost brain performance, even with reduced side effects, is for some a worrying idea as it can be viewed as the intellectual equivalent of steroids in sports. What may be illegal in sports may simply be an open industry secret in business, something not talked about but something that everyone does. There is, however, an emerging discussion on the ethics of such practices, and as cognitive enhancement is often rolled into other debates on the merits on transhumanism.[52] Wide-scale military use could inadvertently legitimatize such activities. Like other stimulants, rigidly controlled military use of cognitive enhancers may actually be less controversial than the prospect of such usage becoming commonplace in the civilian world.

It cannot be overstated that military service exposes the warfighter to extreme amounts of stress. Ongoing research is both confirming the linkage between stress and less-than-optimal performance as well as finding ways to deal with stress to improve performance. Additionally, psychological stress after deployment is presenting costs to both individuals as well as military and veteran health care. A 2012 Congressional Budget Office (CBO) report highlighted the significant cost difference in treating recent veterans with post-traumatic stress disorder (PTSD) and those without—$8,300 with PTSD (to $13,800 when combined with traumatic brain injury (TBI)) versus $2,400 for those not diagnosed with PTSD.[53] Now these are average costs; individuals react to stress differently, meaning susceptibility to and severity of PTSD, and associated treatment costs will be different. Personal costs, however, are often incalculable.

Technology continues to increase survivability for bodies, and with greater understanding of how the body and mind are connected, technology will be used to help protect the mind. The identification of TBI is one such advance. The combination of protective gear that allows survival with reduced bodily injury and enemies that favor the use of explosive traps has led to a seeming increase in neurological injury.[54] This has led to a redesign of combat helmets that better insulate the brain from shock. On the diagnostic side there has been growing attention to TBI both from the military experience, as well as from the world of professional sports, where the long-term effects of hard hits to the head are now being understood. TBI has been linked to decreased cognitive performance, as well as behavioral changes that may haunt a soldier years after service. Although it would seem the more that is discovered, the more vulnerable people appear, the outcome of better understanding injury mechanisms is leading to greater levels of protection against what were previously unknown threats.

Training regimes, backed up by technology borne out of cognitive research, have the potential to reduce the amount of stress on the battlefield, and reduce the amount of psychological trauma afterward. Virtual-reality simulations, in addition to providing effective, safe, convenient, and low-cost training opportunities are also providing a window into the workings of a soldier's mind under many of the same stresses faced in combat. Programs such as the Stress Resilience in Virtual Environments (STRIVE) Project are combining simulated combat and noncombat situations with active monitoring of stress and other emotional markers to help prepare soldiers for deployment.[55]

The reality of military service is that there is a potential that one will be called on to take another person's life. Though such acts are necessary for the protection of others, and indeed securing entire societies, it is still for the average person a traumatic act. Scholars such as retired lieutenant colonel Dave Grossman and others have written extensively on the psychological costs of killing. In the context of emerging military technologies, this is becoming a concern with drone operators who, thanks to advanced optical sensors, may have an up-close view of their actions and the results despite being physically located a continent away.[56] At the same time, many in civilian society find

it very disturbing that there are training regimes designed for the purpose of preparing young adults for the act of fighting and killing. It is therefore of no surprise that the use of biotech products to assist in this preparation would be controversial.[57]

To be clear there is little need in a modern professional military for uncontrolled violence. In this media- and information-saturated era, the lack of judgment and outright crimes of a very small number of uniformed personnel have had a magnified effect, leading to unjust charges against all past and current serving personnel.[58] Additionally, these sensationalized incidents are often being twisted by anti-Western forces as propaganda and justification for terrorist attacks. Excess use of force is clearly something to be avoided, not just on humanitarian grounds, but for purely practical reasons. Overall it must be remembered that the current Western paradigm for military action has been on increasing control over destructive force. Therefore it would seem more likely that military leadership would desire a greater control over aggressive behavior in military personnel than any kind of enhancement of aggression. Perhaps it is better to say that what is wanted is not increased aggression, but more on-demand control over the emotional states and mental stress while in combat. Refined knowledge of the neurotransmitters, hormones, and other brain activity in stressful situations is being applied to produce a calmer more effective soldier.

The human brain is perhaps the most complex organ known, but ongoing research is slowly revealing its secrets. A national security and law enforcement spin-on from the existing medical and recreational demand for portable and low-cost brain-activity monitoring is interest in using this technology as a lie detection or interrogation tool. With international terrorism remaining an ongoing threat to the West, the threats that brain-scanning technology is meant to counter are clearly known. Many intelligence and law-enforcement tasks revolve around determining whether a subject is relaying information accurately and techniques for probing the mind, noninvasively, seem like an ideal capability to develop.

Technology is providing a better picture of how mind and body work together. Sensors of increased resolution are linking thought, behavior, and actions with brainwaves, measures of brain's electrical field by electroencephalography (EEG), blood flow by functional magnetic resonance imaging (fMRI), and other measures. There is enough resolution to allow brain activity to maneuver wheelchairs and operate prosthetic limbs, though not to the level where thoughts and words can be captured. This research is also being refined for use as a means of lie detection. It is hoped that the neurological activity involved with lying, and other responses useful during an interrogation, would provide a better signature than body language and other physiological responses.

Among the techniques that have been studied by law enforcement and military agencies is brain fingerprinting. This technique looks for the presence of brain-wave patterns associated with recognition, or as one of leading proponents and developers Dr. Lawrence A. Farwell puts it, an "aha!" response.[59] Not specifically a lie detector, brain fingerprinting, through the combination of an EEG and carefully designed line of questioning, purports to be able to detect the presence of specific information. For example, brain fingerprinting could use recognition of the phrase, "No, not the mind probe," to separate out classic *Doctor Who* fans at a science fiction convention. A more practical use would be to quickly separate terrorist suspects from the innocent on the basis of whether or not they recognized specific knowledge of terrorist activities, personnel, and paraphernalia. Now as this is simply a test of recognition; investigators will still have to be mindful of context—an innocent relative of a known terrorist would have a strong recognition response to stimulus such as pictures of their dangerous relation. It is hoped by their backers that brain fingerprinting and related lie-detection techniques based on neurological observation will become trusted investigative and judicial tools.

Going further is the more controversial subject of using biometrics to scan a population for signs of terrorist and criminal activity before the actual attack or crime. Though the concept itself is criticized as being part of the Big Brother state, the Department of Homeland Security has had several programs aimed at identifying not just individuals, but also intent based on recognizing emotional and behavioral cues.[60] This is similar to data mining, except instead of looking for precursor transactions to terrorist or criminal acts in a person's digital paper trail, looks for subtle behavioral signs that are theorized to be precursors to terrorist or criminal acts in the physical world. As of 2011, testing in the field has begun. Opinions vary on these programs as either promising security tools, massive invasions of privacy, misspent funding,[61] or some combination of the three.

The prospect of a being able to recognize intent, concealment, and even guilt through these new technologies raises many ethical questions. A major question is effectiveness, how reliable must the technology be before it is employed. If the reliability rate of detecting evil intent is insufficient it can at best be only used as a screen for other methods. In the Global War on Terror, there have been several incidents of detention and allegations of torture of people who were later proved to be innocent.[62] At the same time there is the worry that terrorists may be able to slip through the system, again for reasons of human or systemic error. Backers of neurological, cognitive, and behavioral techniques claim that these technologies will mitigate the occurrences of both unpleasant cases.[63]

Related is the question of how far may pressure tactics be permitted if concealment is detected. Parts of biotech are geared toward more individualized medicine; it is conceivable that branches of biotech could be applied to individualizing interrogation. As former secretary for defense Donald Rumsfeld has proven, some people regard standing for hours on end as part of a healthy day at work, whereas for others it is regarded as torture. In practical terms these technologies could allow for a systematic and unbiased separation of detainees who respond to strenuous questioning, and those who require additional stress. This in theory would protect some from unnecessary pressure being applied, but then raises the question of what to do in particularly hard cases. These are polarizing questions, and the introduction of new interrogation technology, no matter how accurate, will not make them go away.

Genetics

The study of DNA, genetics, and the way the instructions for all life is encoded has moved on from the generally benign world of discovery, to the more controversial world of application. An organism's genes may be studied to determine its traits and characteristics, including its susceptibility to disease, environmental conditions, and toxins. Though the costs still remain high, and our knowledge of what each gene does is still limited,[64] there are fears that the application of genetic technology will bring about genetic discrimination, where opportunities may be barred to individuals on the basis of their DNA. Instead of screening on the basis of medical health, merit, and integrity, all things that an individual has an influence over, there is concern that medical insurance and other aspects of life could be screened based on genetic probability. As the military is an organization that must screen its personnel for fitness and suitability for membership, the question of whether genetics should be included in recruitment screening will be a possibility as DNA analysis technology becomes more widespread.

Control over genetics allows the mixing of genes from one organism into another, allowing one animal to express traits that it would never do so in nature. Genes are ultimately chains of molecules, chemistry in other words, meaning that with enough control over the formation of specific molecules, completely artificial genes can be constructed to achieve desired results. Not only does this allow the generation of life forms from just genetic data, but also potentially the creation of designer life forms. The molecular-level control needed to construct artificial DNA should be familiar as this is nanotechnology from the previous chapter in all but name. Genetic manipulation leads directly to biotechnology's capacity to produce weapons of mass destruction (WMDs). Even without its weaponization potential, there is debate over how to use the growing mastery over genetics; as in the genome, the complete set of genetic material for an organism is both the definition of its existence and instructions for its destiny.

Genetics: Biowarfare Potential

Biological weapons include both living pathogens, such as bacteria, germs, and virus, and toxins generated by living organisms, such as the ricin used in the infamous 1978 assassination of Bulgarian dissident Georgi Markov. Their utility in warfare has been very controversial; some regard them as terror weapons of limited tactical or strategic value due to their relatively slow and unpredictable effects compared to traditional kinetic options. Others have come to fear them as the "poor man's nuclear bomb," leading to its inclusion as a WMD. Without killing, illness is enough for pathogens to have debilitating tactical and strategic effects. There is great fear that commercial air travel and a generally more interconnected world may allow released infectious biowarfare agents to spread globally with catastrophic results. The limited spread and casualty numbers of pandemics such as SARS and H1N1 influenzas on the other hand indicate that the reality of a biowarfare attack or accident may not be as simple as the collapse of Western civilization. Indeed the limited casualty rate of the 2001 anthrax attacks against the offices of U.S. politicians and media would tend to indicate the difficulty in employing biological weapons. At the same time these incidents did generate a lot of panic, disrupted operations of these offices as well of the U.S. Postal Service, which was used unwittingly as the delivery mechanism, and did kill five U.S. citizens and sickened many others.[65] Perhaps beneficially these outbreaks and incidents have brought attention to the threat of infectious pandemics, both natural and manmade.

Befitting the label "poor man's nuclear bomb," biological and chemical weapons (toxins that are not necessarily from biological sources) figure prominently in asymmetric-warfare threats. Chemical and biological weapons are among the unconventional ways it is feared that a significantly mismatched opponent may choose to strike at the United States. Considering the U.S. strength in conventional and nuclear weapons, a rogue nation, by definition ignoring international norms, may resort to combination of state-sponsored terrorism with what mass-casualty weapons are available to it. With the expertise and equipment associated with chemical and biological weapons becoming more accessible, independent terrorist groups may choose these options as well. The Japanese Aum Shinrikyo doomsday cult used sarin nerve gas in several deadly attacks, culminating in 1995 with coordinated attacks of the Tokyo subway. It is known that Aum Shinrikyo also had invested in an unsuccessful biological weapons program.[66] Biotechnology has moved on

in the last 20 years, and the challenges that stopped Aum Shinrikyo may no longer be relevant today.

There are two kinds of dual use with regard to modern biological weapons: research and development toward biological defenses can be easily converted into offensive biological weapons,[67] and the dual-use nature of the biotech industry itself. To develop vaccines and understand the threat posed by specific biological agents it is necessary to study that pathogen in detail. This includes information on how to culture a pathogen, and how to process it into a weapon such as an aerosol or particle suitable for dispersal over a wide area. The very same skill base and industrial equipment may be found creating large quantities of biological weapons agents, vaccines against the former, as well as medical products in general. With technology allowing the construction of smaller labs there is increasing potential for small undetectable biological weapons labs.

In addition to production, many of the biotech opportunities discussed earlier, such as targeted medicines and technologies to help deliver drugs past the body's defenses can be applied to biowarfare compounds to make them more lethal and importantly, in light of their questionable utility, more effective as weapons. Genetic engineering and synthetic biology can insert genes into pathogens to increase their survivability against both the immune system, as well as the environmental conditions that make biowarfare unpredictable. Toxins can be coated in molecular shells that evade the body's natural filters to deliver their payload to specific parts of the body.

In 2005, the Centers for Disease Control and Prevention (CDC) announced it had reconstructed the influenza virus strain responsible for the 1918 pandemic as part of efforts to understand this and related threats such as current bird and swine flus.[68] The techniques used by the CDC and others pioneering synthetic genomes[69] could also be harnessed for the purpose of bringing back other past killers, such as small pox, which have potential as bioweapons. It is of note that since the eradication of small pox, the CDC and its Russian counterpart both hold onto the last samples of small pox for, among other reasons, use as a safeguard against the event that the eradication of this killer disease was declared prematurely. At the time there were fears that these small pox samples could be used in biological weapons programs. Now with synthetic biology becoming a refined mainstream tool of biology and biotech, all that is needed to resurrect the virus is data on its genome.

Added to the mix are the beginnings of open-source biotech and biohacking, modeled after open-source equivalents in the computer field, as a means to encourage new discoveries and creative uses for genetics without the limits of restrictive copyright patents, and indeed to promote the free exchange of biotech components (genetic components). The international genetically engineered machine (iGEM) competition, started at MIT in 2005, has undergraduates from around the world to assemble machines out of biological parts, which are then inserted into living cells.[70] That undergraduates, high school students, and the general public are taking an active interest in synthetic biology skill set, is both inspirational and frightening. Though at the moment somewhat overstated, many of the tools and skills available to hobbyists may have applications in engineering biological weapons. Indeed if the parallels to tinkering with computers are carried further, harmless fun with the *E. coli* bacteria[71] will evolve overtime into rampant and widespread availability of malicious biological organisms and compounds created in underground labs staffed by brilliant, but unethical, enthusiasts. It remains to be seen what kind of safeguards will develop as more people take an active interest in tinkering with the instruction set of life itself.

The balance between biotechnology as a defense against biological weapons and as an enabler for biological attack is similarly unclear. The present prevailing notion is that the life sciences should be used to improve health and quality of life—increasing the likelihood that biotechnology will be overall beneficial, though some debate exists as to what definitions of beneficial apply. However, as history has shown that is not a universal belief, nor is it a straightforward one. Putting aside the dual-use nature of biological weapons research, at certain points in history the United States and other nations did believe that biological weapons had deterrent value, meaning that work on these most abhorred of weapons was linked to maintaining peace. As the threat of biological weapons cannot be wished away, it is expected that biotechnology will simply continue to be both a tool to mitigate the threat, and be under suspicion of enhancing it.

Genetics: Shifts in Global Production

Much less panic causing, but probably of more day-to-day relevance to the military is genetic engineering's potential to produce materials. Nature is already adept at using exponential growth to cover the earth in all manners of "manufactured" products. It must be remembered that without life producing them, many of the complex molecules that make up proteins and other cellular structures would simply not exist. All genetic engineering would be doing is inserting genes to cause organisms to produce molecules that would be useful for very specific human purposes.

Genetically engineered goats that produce spiders silk[72] gain attention in part due to the somewhat disturbing concept of making a large mammal produce something commonly thought of as only being produced by small insects. On closer analysis, the key components of spider silk and milk are both proteins, though ones with vastly different mechanical properties.

There are no natural reasons for spider silk protein to exist in milk; however, there are man-made ones. Artificial spider silk has long been suggested as a future material for high strength but lightweight applications such as body armor. The principal barriers to use are the challenges in bulk production. Biotechnology is in an odd way of potentially returning soft body armor to its roots. Early bullet-resistant vests were made of layers of silk. Real silk comes from silkworms, which started being harnessed for silk production centuries ago.

Of less surprise to the general public is biofuel production. Fossil fuels are by some definitions organic products; at one point in time their source materials were living plants and other organisms such as plankton. This dead organic matter after being trapped under layers of sediment for periods of time measured in eons is compressed until it forms fossil fuel, which one specifically depending on the starting materials and nature of the geological events that formed it. Given enough energy any organic material can be processed into substitutes for fossil fuels. An example of this is oil from the Canadian tar sands, which is a purely industrial process.

Biofuels are fuels produced generally from harvested plant matter, though feed stocks may also include dead animal matter. Biofuels include ethyl alcohol (ethanol), which is produced in the same method as alcoholic beverages by the fermentation process, but for compatibility with existing engines must be blended with traditional petroleum products. Seed oils, a familiar item in most kitchens, have also been processed into fuels, some of which have already been tested by the U.S. military. In 2011, a U.S. Navy trainer was test flown with a fuel mix that included a component produced from Camelina seed oil.[73]

Genetically engineered plants may provide both better yields of feed stocks, such as sugars and starches. This technology has also been used to produce strains of bacteria able to process organic waste materials such as cellulose.[74] Various labs in recent years have been able to modify bacteria to produce usable fuel directly,[75] in a process again resembling industrial fermentation; however, as it is chemically identical to traditionally produced fuels, it does not have to be blended like ethanol and other biofuels.

There is, however, a price to this—currently available biofuels are more expensive than fuels produced from traditional petroleum sources. Indeed most alternative sources of petroleum products, including tar sands, have a tendency to be more expensive than crude oil due to the need for more processing. At the time of writing there was an ongoing controversy over continued funding of U.S. military biofuel projects in light of severe funding constraints to other priorities.[76] This, however, may not always be the case as traditional petroleum prices are subject to large price fluctuations, as they did toward the end of the first decade of the 21st century. Though controversial, government-subsidized research on biofuels, including that from the military, may potentially lower prices, as research into directly using biotech to produce "drop-in" biofuels creates a new, and practically inexhaustible, source of pure fuels. Alternatively both demand and prices for fuel may simply remain high, allowing for biofuel costs to be lowered while still being a profitable investment.

Another political dimension to biofuels is energy independence for the United States. There is a perception that the United States obtains too much of its fuel by importing it from dangerous parts of the world—including linking doing business with the Middle East with indirect support for terrorism.[77] This is a complex issue, as even the definitions of energy independence and energy security are open to debate.[78] Some view increasing domestic supplies of oil as a bulwark against foreign pressure from oil-supplying nations. This has happened before, in the 1970s, when Middle Eastern nations put an embargo on oil exports to the United States over U.S. support of Israel. Use of oil as a blunt political tool would be difficult as all who participate in the petroleum market would be affected. Even the linkage of oil imports to instability in the Middle East and elsewhere is questionable. Increasing domestic production of petroleum would have little effect on the global price of oil,[79] and therefore little impact on oil revenues (accused of directly or indirectly being funneled toward terrorism).

Man and Machine: Workspaces and Mobile Infantry

While waiting for the advent of artificial intelligence, improvements to the interface between humans and machine will mitigate the limits of the slow piece of wetware still required in some form for all weapon systems. Even experienced computer users sometimes find themselves wishing that the computer could read their intent, instead of their actions, when trying to get a computer to perform some desired action. Often it is just human error that prevents people from getting the most out of the computer system, and other times it is the interface that is the barrier to getting the most out of technology. Although it is often said that people limit what weapon systems can accomplish, another limiting factor is the interface between operator and machine. Cognitive research is not just about drugs to improve mental alertness; it also includes branches that study just how people interpret information, and perhaps how the rate information is supplied can be optimized.

The military has been on the forefront of improving the linkages between man and machine. Decades ago the first heads-up-display (HUD) and hands-on-throttle-and-stick (HOTAS) were introduced into combat aircraft, allowing a pilot to conduct an attack without looking down at cockpit instruments

and displays. These innovations only started making inroads into civil aviation recently, and are available in some higher-end automobiles. The computer revolution has allowed HUD systems to become small enough to be fit safely into helmets. In the civilian world, where overburdening the neck under high g-forces is not so much of a problem, wearable computer interfaces, such as Google's recently unveiled Project Glass, are promising to bring head-mounted displays (HMD) to the masses. Additionally, the somewhat maligned[80] Land Warrior program did deploy monocular (one eye) displays with soldiers sent to Iraq and Afghanistan, despite the program being largely defunded.[81] Prototypes now exist of displays reduced down to contact lenses as part of DARPA-funded research.[82]

The technology being worn has certainly made progress; however, what is of more importance is the information being displayed. Sometimes called synthetic vision systems, the current buzzword is augmented reality. Provided the display knows where it is and how it is oriented, it can overlay data over the seen image. For military users this will include imagery generated by night vision or thermal-imaging equipment. Aviators may have a complete unobstructed view in all directions (or at least in all directions there is sensor coverage) to allow for superior situational awareness.[83] As with all hi-tech military concepts, augmented reality is expected to be networked, meaning commanders monitoring the mission from headquarters may not only be able to see the same thing the a soldier on patrol is seeing, but also be able to mark for attention objects and people of interest found in the soldier's field of view. Indeed some application of cognitive research aims specifically to assist enhance how specific information is communicated.

Essentially with augmented reality, it is hoped that much of the thinking can be offloaded to a computer, or specialists in headquarters. Augmented reality, if used as the interface for earlier net-centric warfare concepts, could help integrate infantry[84] into the network of vehicle- and drone-based sensors, allowing for a target seen by one to be passed on to another even without direct line of sight. Another example would be autonomous language translation software generating subtitles that could be overlaid in a soldier's field of view. This would allow the soldier to maintain eye contact with the foreign speaker, understand what was being said despite having no knowledge of the language, and importantly provide feedback that would help break communication barriers. A rosy picture to be sure, but as long as winning hearts and minds remains a goal, technology that helps to build rapport with the locals will be as important as applications that allow a soldier to destroy targets that they cannot naturally see.

Part of the interface is supplying information; the other part is inputting information. With the rise of social networking this now goes beyond issuing commands to worn equipment and includes communicating with others.

Eye tracking is the direct opposite of augmented reality displays; instead of a computer outputting an overlay of important information, what the eyes are focused on is used as an input. In the many areas of cognitive science, eye tracking generates some of data points involved with research on learning, perception, and even wakefulness.[85] Commercially available eye tracking is available as a mouse/trackball substitute. The closest military equivalent in service right now would be head-tracking helmets used in some fighter aircraft to provide weapon cueing.

Other minimalist computer input options include gesture and voice recognition. Leveraging off both the consumer electronics industry, and the field of biometrics, both these technologies hope to be able to translate natural verbal and nonverbal communications into something a computer can understand. If cameras can recognize intent just from subtle movement and body language, then it is not much of a leap that software can be devised to recognize movement and gestures as commands. Years before camera-based systems for personal gaming consoles became common, there was speculation that sensors embedded in gloves could be used as an input for silent communications between networked soldiers.[86] A limited form of voice recognition is already available in the Eurofighter Typhoon,[87] and may be available in the U.S. F-35 Lightning II,[88] a multiservice aircraft still under development at the time of writing. The challenge is, however, in developing software able to accommodate the many variations in speech within the same language. Combat conditions may also impact accuracy, limiting their application to noncritical tasks.

As noted earlier, brain waves can be read with enough resolution to navigate wheelchairs. Like the eye tracking, there are very rudimentary brain-wave-reading computer interfaces, brain-computer interfaces (BCI), available to the public. Although the technology is still in its infancy, it is of interest as a means of controlling prosthetics. DARPA funding (over $70 million)[89] [90] is behind the Revolutionizing Prosthetics 2009, which aims to produce a neurally controlled artificial arm. Instead of reading muscle contractions as in current myoelectric arms, DARPA and its partners hope to hook a robotic arm directly to the brain for control. Two years later this program was hitting headlines again with the Food and Drug Administration (FDA) announcing that it would be fast tracking the approval process for the fruits of this project, the implantable sensor to control the arm, it entered human testing.[91] For many military service has meant loss of limbs and, therefore, it is understandable why the military is involved with research and development into artificial limbs, as well as making it available to soldier-amputees first.[92]

Associated with a brain control of a prosthetic would be the prosthetic providing sensory feedback such as touch, pressure, heat, and with a high-enough

"resolution" ability to feed information into the brain, texture. Although it is unclear if a machine will be able to totally replace flesh and bone, without sensory feedback the artificial arm would only be a modest improvement over current-day prosthetics. Though of very low resolution so far, and limited in what type of vision loss they correct, visual prosthesis has already entered human trials.[93]

Avoiding the regulatory difficulties of an implant would be the powered exoskeleton. Also called a wearable robot, the powered exoskeleton also avoids the many technical barriers and troubling ethical problems of artificial intelligence or remote-control warfare by putting the combatant directly in the middle of the fighting, but enhanced by robotics. Alternatively, this is the combination of sometimes unpredictable and/or cognitively weak humans with the maintenance and power requirements of walking robots. There is truth in both descriptions of present-day exoskeleton technology today. In the near term, real-world progress is being made on military exoskeletons for use in more-benign settings as logistical machinery, basically a walking forklift.

Military interest in the powered exoskeleton goes back decades as a means to amplify strength for logistical tasks. In the 1960s General Electric attempted to produce a powered exoskeleton, the Handiman, to magnify the user's strength by 25 times.[94] Funded by the military, among the tasks for this large apparatus was loading ordnance onto aircraft onboard aircraft carriers,[95] something which to this day still requires a small team of sailors to perform. As a form of human amplification, Handiman was meant to be controlled by simply replicating the movement of the limbs it was worn over. Weight, control, and power problems have, however, stopped Handiman and other powered exoskeleton projects from being viable until recently.

Today's exoskeletons are much smaller than Handiman, with more achievable goals of simply taking the burden of an oversized combat load off the soldier,[96] or allowing those suffering from physical weakness or loss of mobility due to paralysis to walk again.[97] Faster computers and smaller microelectronic sensors have solved many of the control and balance problems, much in the same way they have only recently solved the many challenges of walking robots. Both an exoskeleton used as a mobility device for the paralyzed and one that will allow a sleeping soldier to continue marching are simply walking robots that have space reserved for the operator's legs and torso. The two current prototypes that DARPA is funding, the XOS series by Sarcos/Raytheon and the Human Universal Load Carrier (HULC) by Berkley/Lockheed Martin, have agility requirements.[98] Despite seeming being in competition, both exoskeleton projects seem to be fulfilling different roles. The former is a tethered system that includes amplified arms and appears more geared toward logistical work. The later is self-contained but comprises only a pair of powered legs meant, as it name implies, to only assist with the carriage of heavier loads than the standard combat pack, implying a role in augmenting combat endurance, though it also could be used for logistical tasks.

Despite smaller more efficient electrical systems (and the loss of the heavy hydraulics found in early concepts like Handiman) battery life is still measured in hours. This even applies to Lockheed's HULC, where there is some talk of deployment for testing in warzones such as Afghanistan.[99] Advance batteries, fuel cells, artificial muscles, and replacing electrical actuators with chemically powered ones are all on the table as far as ways to extend the power supply for an exoskeleton with enough endurance for extended combat operations are concerned.[100] Otherwise the exoskeleton will remain tethered to a power supply, much as the XOS2 prototype is right now.

Limits: How Far Is a Society Willing to Go

There are fears as to how far military biotechnology research will go. The drug-enhanced "super soldier" is a common trope for some in the media wanting to portray the military as ruthless and reckless. Unlike athletics, the military would seem to have the option to go further than just better rations, training programs, and computer interfaces. If relatively safe and side-effect-free performance-enhancement treatments can be developed, for the military at least, their use would not be problematic from a fair play standpoint—the stated goal of all military R&D is to produce an unfair advantage. However, this is a very simplistic view; the use of biotech to enhance the body is somewhat more complex. Reining in the nightmare, and for some the dream, of the "super soldier" are the many practical challenges and ethical barriers.

The real-world history of pharmaceutical means of enhancing body and mind has had a very checkered past. Many of these existing drugs are important medical therapies, but also have found many illegal uses ranging from recreational drug abuse to cheating in competitive sports. Under medical supervision they can give hope, but in the wrong hands more often than not they carry legal and health risks. Even under medical supervision, therapeutic use of steroids, although life saving in one area of the body, may cause lasting damage somewhere else. For doctors and patients it is often a difficult choice of debilitating side effects or death. It is important to remember that many of the promises of molecular and other better-targeted forms of medicine are just that—promises. The human body is the most complex organism known, with many secrets enduring continued assault by the life sciences. Although it is likely that efforts to reduce side effects will be successful, it is unlikely that all side effects will be eliminated.

Again it is practical needs that will drive what forms of pharmaceutical and other augmentation of physical abilities will be used. Even with limited

personal costs, the benefits may not be worth the financial costs to the system as they would simply end up being only marginal improvements over already effective physical training methods and enforcement of existing standards. If one chooses a military career, one probably has been made well aware of the physical-fitness standards for particular paths to career success. If biotech solutions may not be worthwhile for general issue, their use by individuals may carry the same repercussions from the organization as "cheating." Alternatively there may be pressures within the organization to turn a blind eye or encourage such behavior. In a contemporary real-world military context, sometimes seeking out a fair fight is a foolhardy act, other times a level playing field is important to honor, unit cohesion, the organization, and the mission of defending the country.

It is entirely conceivable that some biotech options for enhanced performance may be available in the civilian world but not available within the military supply chain for reasons of policy. During the wars in Iraq and Afghanistan some controversy arose over the use of privately bought body armor.[101] Early in those conflicts there were supply problems with body armor, leading some soldiers to believe that to increase their own chances of survivability they had to invest in their own protective gear. The Department of Defense's position on the other hand was that the unregulated body armor may have been of an inferior quality to the standard issue. Perhaps cognitive and other biotech enhancements will be future nonstandard pieces of "equipment" that will put soldiers in conflict with military leadership.

Ethical considerations over applying biotech to enhance the warfighter mirror the general debate over how far biotech and other emerging technologies should be used to directly change people and indeed societies.[102] Distribution of the benefits of biotechnology is a common ethical debate brought up by futurists trying to predict how emerging technologies will change the world. The question of how far to go does not exist in a vacuum, others are engaging in research and development in these same emerging industries. Under most theories on international relations, biotech should be used as a tool to enhance a nation's place in the world; however, not all theories would agree on using it as a tool to enhance hard power. Cooperation on more benign areas of biotech, and even select militarized ones, could have security payoffs. Again it is a matter of what works.

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