MIND WARS

Coursera Excerpt

BRAIN SCIENCE AND THE MILITARY IN THE 21ST CENTURY

JONATHAN D. MORENO

PRAISE FOR

Mind Wars: Brain Research and the Military in the 21st Century

"Quietly provocative . . . Moreno takes an evenhanded, thorough look at how deeply the intelligence and defense communities are involved in many of those advances and the mindfields that might lie ahead."

—Cleveland *Plain Dealer*

"Even-handed and thought-provoking. [*Mind Wars*] is very readable, and easily accessible to people without a background in neuroscience."

—*Neurophilosophy* at the *Guardian*

"An exhilarating and anxiety-provoking whirlwind tour of recent developments in neuroscience that possess defense or national security potential . . . groundbreaking." —*American Journal of Bioethics (AJOB)*

"A fascinating and sometimes unsettling book. . . . Any academic involvement in military research presents an ethical dilemma, and Moreno's exploration of this theme is one of the most interesting aspects of the book."

—*Nature*

"Crisply written . . . praiseworthy." —*Publishers Weekly*

"Renowned bioethics authority Moreno travels to the nexus of brain science, engineering, and national security to explore the connections between neuroscience research and national defense agencies. . . . Given the topic's provocative nature, this is recommended for all science and bioethics collections."

—*Library Journal*

"Raises serious social and policy questions . . . deserves a wide readership."

—*CHOICE*

"This will certainly be the source book on the ways in which neurobiology may rewrite the rules of warfare, spying and intelligence collection in the twenty-first century."

—ARTHUR L. CAPLAN, Director of the Center for Bioethics at the University of Pennsylvania

"Few people ever think about brain research as a national security discipline. This intriguing and provocative book lays out how neurotechnologies for brain analysis, repair and enhancement can be multi-purpose and serve both good and nefarious functions."

—ALAN I. LESHNER, Ph.D., American Association for the Advancement of Science (AAAS) CEO and *Science* Executive Publisher

"Fascinating, clear-headed, optimistic, and lucidly written, *Mind Wars* makes a compelling yet nuanced case for scientific progress in the area of neurology enhancement and for the transparent collaboration of the academy and the military."

—SALLY SATEL, M.D., author of *PC, M.D.: How Political Correctness Is Corrupting Medicine* and Resident Scholar at American Enterprise Institute

---

PRAISE FOR

The Body Politic: The Battle Over Science in America

A ***Kirkus Reviews*** Best Book of the Year and ***Scientific American*** Book Club selection

"An impassioned defense of scientific study . . . an essential dose of logic."
—*Salon*

"Articulate, timely and impassioned . . . [an] important book."
—*Times Higher Education*

"The most penetrating characterization and analysis of the shrill political battles fought over the use of our new biotechnologies (and the battles to come)." —*American Journal of Bioethics (AJOB)*

"A timely take on the debate raging over biotechnology breakthroughs."
—*Nature*

"Scholarly, sophisticated and compelling."
—*Washington Independent Review of Books*

"Underscores the strange bedfellow allegiances that may occur in what has been called our 'biological century'." —*Point of Inquiry*

"Erudite and sophisticated . . . provide[s] a historical and philosophical framework to enrich present bioethical debates." —*Real Change*

"[Moreno] illuminates intricate threads of history and complex philosophical arguments. . . . Highly recommended for anyone interested in the[se] vital issues." —*Kirkus Reviews* (starred review)

"An important analysis of the societal currents swirling around volatile scientific issues . . . Moreno delivers a powerful defense of science [and] respects his readers' intelligence in this nuanced and thoughtful book."
—*Publishers Weekly*

"Moreno shows how biological discoveries aggravate cultural tensions, challenge our political system and values, and stimulate debate about the place of science and scientists in America. . . . Sophisticated, useful, and well-written."
—*Library Journal*

"A concise but nuanced account of Enlightenment and post-Enlightenment debates about the role of science in American life."
—*CHOICE*

"It's clear [Moreno] has his thumb on the cultural and historical contexts in which these issues have arisen. . . an excellent addition to any syllabus."
—*ForeWord Reviews*

"A solid addition to any politics collections."
—*Midwest Book Review* (reviewer's choice)

"A must read for anyone who wants to understand science policy today."
—JOHN PODESTA, former White House Chief of Staff and President and CEO of the Center for American Progress

"Since the beginning of our quest to win the Indianapolis 500 our family has believed in the power of technology. The only limits to that technology have been human ones. *The Body Politic* reminds us that in biology as well as engineering, America will always need that pioneer spirit."
—AL UNSER, Sr., AL UNSER, Jr., BOBBY UNSER, Sr., Indianapolis 500 Champions

"A clear-eyed map of the emerging biopolitics—greens, transhumanists, bioconservatives, technoprogressives—and a thoughtful defense of inquiry, innovation, and the liberating power of science."
—WILLIAM SALETAN, author of *Bearing Right: How Conservatives Won the Abortion War* and *Slate* National Correspondent

"This groundbreaking must-read book situates the biological revolution in its historical, philosophical and cultural context and, with almost breathtaking elegance, shows how society may come to define itself by the body politic."
—NITA A. FARAHANY, Associate Professor of Law & Associate Professor of Philosophy, Vanderbilt University; Member, Presidential Commission for the Study of Bioethical Issues

"A penetrating and uncommonly fair-minded analysis of how science is construed, nourished, and antagonized across the rainbow of American thought and belief. Highly recommended."
—TIMOTHY FERRIS, journalist, PBS filmmaker and author of *The Science of Liberty: Democracy, Reason, and the Laws of Nature*

"Provides a fascinating, timely exploration of one our era's most momentous issues."

—JOHN HORGAN, author of *Rational Mysticism* and Director, Center for Science Writings, Stevens Institute of Technology

"*The Body Politic* reminds us that science occurs within a complex context that exerts powerful forces upon scientists, public officials, advocacy groups, and patients. Moreno has written the kind of book that needed to be written, combining detailed research, enlightened analysis, and an important message, all wrapped in accessible text."

—ERIC M. MESLIN, Ph.D., Director, Indiana University Center for Bioethics

"A beautiful book."

—JAY SCHULKIN, Ph.D., Research Professor, Department of Neuroscience, Georgetown University

"Required reading for anyone who wants to understand the history of American political thought about science, the dynamics of current controversies such as the stem cell debate, and the battle between those who see science as the route to a better future and those who see within the science the potential for a loss of our sense of human distinctiveness and dignity."

—PAUL WOLPE, Ph.D., Director, Center for Ethics, Emory University and Chief of Bioethics for the National Aeronautics and Space Administration (NASA)

"An excellent guide . . . In his highly readable and provocative book, Moreno makes clear that progress, including biotechnological progress, is still America's most important product."

—*Reason* magazine

MIND WARS

ALSO BY JONATHAN D. MORENO

The Body Politic: The Battle Over Science in America

Is There an Ethicist in the House? On the Cutting Edge of Bioethics

Undue Risk: Secret State Experiments on Humans

Deciding Together: Bioethics and Moral Consensus

COAUTHORED BOOKS

Ethics in Clinical Practice

Discourse in the Social Sciences: Strategies for Translating Models of Mental Illness

EDITED WORKS

Progress in Bioethics: Science, Policy, and Politics

Science Next: Innovation for the Common Good

Ethical Guidelines for Innovative Surgery

In the Wake of Terror: Medicine and Morality in a Time of Crisis

Ethical and Regulatory Aspects of Clinical Research: Readings and Commentary

Arguing Euthanasia: The Controversy over Mercy Killing, Assisted Suicide, and the "Right to Die"

Paying the Doctor: Health Policy and Physician Reimbursement

The Qualitative-Quantitative Distinction in the Social Sciences

MIND WARS

BRAIN SCIENCE AND THE MILITARY IN THE TWENTY-FIRST CENTURY

JONATHAN D. MORENO

BELLEVUE LITERARY PRESS
NEW YORK

First published in trade paperback in the United States in 2012 by
Bellevue Literary Press, New York

For information contact:
Bellevue Literary Press
NYU School of Medicine
350 First Avenue
OBV A612
New York, NY 10016

Mind Wars: Brain Research and National Defense was published in hardcover by Dana Press, New York, copyright © 2006 by Jonathan Moreno.

Bellevue Literary Press would like to thank all its generous donors—individuals and foundations—for their support.

Cataloging-in-Publication Data is available
from the Library of Congress.

Book design and composition by Mulberry Tree Press, Inc.
Manufactured in the United States of America.
first trade paperback edition

1 3 5 7 9 8 6 4 2

ISBN: 978-1-934137-43-7

6
BUILDING BETTER SOLDIERS

THE HUMAN BEING IS THE OLDEST instrument of warfare, as well as both its strongest and weakest link. Human fighters can be spontaneous, adaptive, and creative, but they may also yield to fear, confusion, and exhaustion. Although astonishing and terrifying "improvements" have been made in the devices of conflict over the millennia, the psychobiology of warfighters are still basically the same. They must eat, sleep, detect danger, discern friend from foe, heal when wounded, and so forth. The first state (or nonstate) actor able to build better soldiers using neuroenhancement technologies will have taken an enormous leap in the arms race. As the summary of a 2010 conference at the U.S. Naval Academy observed, "[s]oldier enhancements, through biological or technological augmentation of human capabilities, reduce warfighter risk by providing tactical advantage over the enemy." However better soldiers are built—and there's good reason to believe that the warfighter of the late twenty-first century will be enhanced—the fighter's brain will have been the object of greatest interest.

PERCHANCE NOT TO SLEEP

Fatigue-induced error is already being targeted, as death by "friendly fire" is a shockingly frequent occurrence that can partly be attributed to the chaos and confusion of combat but also to the sleep deprivation that accompanies lengthy engagements. For example, two American pilots accidentally killed four Canadian soldiers and injured eight others in Afghanistan in January 2003. This horrifying incident resulted in the courts-martial of the pilots before the charges were dropped. The tragedy provided an unexpected glimpse into the air force's interest in sleep. Unnoticed by many, the pilots' attorneys pointed out that their clients had been taking Dexedrine, sometimes called the "go pill" in the military, otherwise known as "speed." It was alleged that amphetamines like Dexedrine are commonly prescribed to keep pilots alert for thirty-hour missions, though questions have been raised about their safety. Their use can also lead to drug dependence.

So the U.S. Air Force is considering alternatives to amphetamines, especially a medication that has also gotten the attention of long-distance business travelers who cross time zones: modafinil. Approved by the FDA in 1998 and marketed as Provigil, modafinil is used to treat narcolepsy and to help with the sleep disorders that come with diseases such as Parkinson's, Alzheimer's, and multiple sclerosis. Modafinil, it should be emphasized, is not a stimulant as we've come to understand the term. Rather than bombarding various parts of the brain with arousal signals, modafinil apparently nudges the brain toward wakefulness through specific pathways, perhaps by increasing serotonin levels in the brain stem. The precise mechanism is still not well understood.

The temptation for healthy people to use modafinil as an anti-sleep agent is tremendous; some report that a dose leaves them as refreshed as a short nap. Frequent fliers are already getting prescriptions for the stuff, and it's sure to be the next craze on college campuses among students who want to pull all-nighters or just be able to party hearty for days. Some health educators worry that modafinil will rival or even replace stimulants such as Ritalin, which in turn replaced amphetamines such as Dexedrine that were the "uppers" of choice when I was in college in the early 1970s. Long-distance truck drivers, who too often grab just a few hours of sleep to stay ahead of schedule, are also obvious candidates for use and, perhaps, abuse. Misusing modafinil wouldn't take the familiar form of achieving a "high," but taking it for inappropriate purposes or to an extreme that has not been shown to be risk free.

Another candidate population for the drug is the large number of workers who shift from day to night schedules and back again. They often complain of drowsiness during the work period and insomnia when they want to sleep. The Air Force Office of Scientific Research and a company called Cephalon sponsored a study by Harvard and Penn researchers in which sixteen healthy subjects were deprived of sleep for twenty-eight hours, like shift workers, and then obliged to sleep from 11:00 a.m. to 7:00 p.m. for four days and to stay awake at night. The subjects on modafinil did far better on cognitive tests than those on a sugar pill.

A few news outlets made unconfirmed claims that American soldiers were using modafinil on the way to Baghdad in 2003. That wouldn't be surprising. A solution to sleep has been a minor-league Holy Grail for war planners since time immemorial. Guards at China's Great Wall chewed an herb containing ephedrine; Incan fighters munched on coca leaves; nineteenth-century Bavarian officers gave their men cocaine; several countries' soldiers used amphetamines during World War II; and, of course, armies consume countless tons of caffeine and nicotine. Even modafinil has been around for decades, used by the French Foreign Legion in World War I and, ironically, as a treatment for cocaine addicts. Like so many other compounds, it was taken off the shelf as its other potential properties became apparent. French soldiers took modafinil in the first Gulf War, and the *Guardian* newspaper reported in 2004 that the UK Ministry of Defence had bought twenty-four thousand tablets of the drug.

But is modafinil truly a wonder drug, able to increase both wakefulness and vigilance while amphetamines often cause their users to be anxious and nervous? Double-blinded, placebo-controlled studies have already shown the antisleep properties of modafinil, with some able to stay awake for more than ninety hours. More complicated is the question of when alertness begins to fade. Does the drug mask natural sleep needs but fall short in keeping people as functional as they think they are? This could be critical for pilots and soldiers, who should not overestimate their readiness. In the longer term, the endocrine and immune systems may be compromised by lack of sleep.

Sleepless Soldiers

Military scientists are working on the safety questions. One researcher at the air force's Brooks City–Base in San Antonio told *Pentagram*, an online newsletter, "We are trying to find out if this is better than what we have or just another drug to help pilots stay awake. It's too early to say if it's a better choice right now. All indications say Modafinil is a safer drug, but we don't know that for sure. That's why we go to exhaustive measures to make sure they're [*sic*] safe." Safe in terms of sound judgment in combat, perhaps, but what about the effects down the road for people who have been on and off the drug for years?

The precise function of sleep and the long-term risks associated with sleep deprivation aren't well understood. There is evidence that during sleep, memory and learning are consolidated, and that the brain refreshes its store of energy then. Studies have shown that people who sleep only four hours a day for an extended period show an increase in insulin resistance, a prediabetic symptom. But without a proven explanation for the purpose of sleep, it's hard to assess the downside of doing without, other than the obvious discomfort that nonsleepers experience, the attendant loss of concentration, and the increased accident risks.

An intervention that could minimize sleep while retaining cognitive capacity would be a significant advantage for a military force. Infantrymen commonly subsist on three or four hours of sleep nightly for weeks at a time. Special Forces personnel may be awake for several days in search and rescue operations. As a way to squeeze out more productivity from soldiers, minimizing sleep has long been at the top of the wish list, hence DARPA's Preventing Sleep Deprivation (PSD) program of the early 2000s. One hundred million dollars in grants were spent for research on "prevention of degradation of cognitive performance due to sleep deprivation." As the PSD announcement put it, "As combat systems become more and more sophisticated and reliable, the major limiting factor for operational dominance in a conflict is the warfighter. Eliminating the need for sleep while maintaining the high level of both cognitive and physical performance of the individual will create a fundamental change in warfighting and force employment." DARPA's Defense Sciences Office described the problem as part of the agency's Continuous Assisted Performance program:

> Continued assisted performance really asks a basic question. Can you prevent the cognitive deficits that occur in sleep deprivation from occurring? If you can prevent bad decisions from being made during sleep deprivation, you can dominate the battlefield by limiting the requirement for sleep. If you cannot prevent those changes from occurring, can you reverse them when they have occurred? Or can you create alternate pathways and expand the available memory space, so that people can retain cognitive function under tremendous stress and sleep deprivation?

The PSD effort includes investigations of another class of drugs, the ampakines, which show some promise in treating dementia and symptoms of schizophrenia by improving cognition when used with antipsychotic medication. Unfortunately, so far clinical trials have not found therapeutic value for these drugs. However, results from a biotech company–sponsored study at Wake Forest University using an ampakine drug in sleep-deprived rhesus monkeys were encouraging. The monkeys' performance was reduced 15 to 25 percent when sleep deprived, and reaction times doubled. But when these monkeys got a single dose of Ampakine CX717, their performance deficit was eliminated, as were sleep deprivation changes in their EEG. An unpublished human trial sponsored by the company that makes CX717 reported that sixteen men deprived of a night's sleep did better on memory and attention tests after taking the drug. The scientist who conducted the study said, "We didn't see any adverse events."

Columbia University neuroscientists using fMRI have found that some neural pathways work better than others under sleep-deprived conditions, leading to speculation that it may be possible to train people to use these pathways. Such an approach might avoid the use of drugs. Transcranial magnetic stimulation (TMS) has been used by neurologists for years to make sure that a certain neural circuit is still intact. Using a handheld magnetic coil on the scalp, a very precise current can be passed into the brain, apparently without injury, though a seizure can be triggered if correct practices aren't followed. This seemingly low-risk approach can help both the operator and the subject know when certain pathways are in use, a kind of biofeedback loop.

Modafinil and these other features of the Preventing Sleep Deprivation program are likely only the beginning of intense efforts to control sleep–wake cycles, driven by a multibillion-dollar demand among those who want to sleep only when they want to sleep. *Wired* magazine reported in 2003 that a company called Hypnion, based in Worcester, Massachusetts, is attempting to develop drugs even more effective than modafinil. Hypnion scientists put radio transmitters on animals that have been given experimental drugs to record various functions, including sleep, using a system developed with air force and defense department funding. In the company's labs, transmitters on mice and rats send radio signals to computers that record the drugs' effects on biological processes, particularly the rodents' sleep patterns.

Another possible approach to managing the effects of sleep deprivation is orexin A, a brain hormone that can be inhaled as a nasal spray. In a DARPA-funded study, the spray was shown to boost the cognitive capacity of sleep-deprived monkeys to the normal level, while having no impact on the fully rested primates. The hormone also appears to be rather benign in terms of side effects. As an alternative to pharmacological attempts to manage sleep deprivation, Noah Shachtman reported that the air force sought proposals in 2007 for a "Short-Wavelength Countermeasure for Circadian Desynchrony." This involves exposure to a type of light that "could correct the imbalance between a person's normal sleep pattern 'and the requirements for alert human performance on imposed environmental schedules' . . ." The Society for Light Treatment and Biological Rhythms indicates that light therapy has been useful for treating the symptoms of seasonal affective disorder, sleep phase disorder, jet lag, and other instances of fatiguing malaise.

The neuroscientific key to sleep lies in a part of the hypothalamus called the suprachiasmatic nucleus (SCN), the brain's biological clock that was discovered in 1972. About the size of a pinhead and nestled deep within the brain, the SCN with its roughly twenty thousand neurons is the pacemaker for circadian rhythms in mammals. Scientists have discovered in animal experiments that if the SCN is cut or removed, the sleep–wake cycle can be profoundly disturbed. The SCN's normal twenty-four-hour clock manifests the intimate connection evolution has given us to our terrestrial home. But when people are deprived of light, the SCN runs on a twenty-five-hour clock, so for some reason that is our innate length of a single day, a fact that helps explain insomnia and other sleep disorders in people who are blind. Though subject to some variation, the clock can be reset by exposure to light signals transmitted from the retina or by other time cues, such as a meal at an odd hour.

Scientists who are not directly involved in the PSD program or its funding seem moderately hopeful that the research can bear fruit. The distinguished Harvard physician and neurobiologist Jerome Groopman has written that

> the widespread assumption that sleep is necessary was supported by early studies of sleep-deprived rats: they suffered deterioration not only in behavior but in body metabolism and immune defenses. As repeated experiments have verified, when rodents are prevented from sleeping they often die of sepsis, with some succumbing after only five days, the hardiest lasting a full month. Yet such effects have not been seen in human subjects. And, surprisingly, there is very little hard data showing that prolonged sleep deprivation truly has deleterious effects on us. The lore that it can cause psychosis dates to the Korean War, when Chinese Communists were said to torture prisoners by preventing them from sleeping; however, later researchers have concluded that the psychosis resulted from the kinds of stimuli and stresses applied by torturers under these gruesome conditions, rather than from the lack of sleep per se.

And Groopman quotes Penn sleep researcher David Dinges, who raises a provocative question about Boeing's plans for a passenger jetliner that will fly around the Earth and need to land only once in twenty hours. "How should the crew sleep, if at all? What are the rules that apply to sustain work on flights like that?" This problem is only one of a number that confront a culture that has been trying to reduce its dependence on sleep since the Industrial Revolution, as Dinges views it. "Now is the time to have an open and frank discussion on how far we will go as a culture, what are our priorities, how regularly do we want to manipulate our brain chemistry? What are the limits?"

Whatever the limits are or should be for the civilian world, security issues may be seen as superseding them. In fact, nonhuman mammals may hold the key that will change evolutionary sleep patterns once and for all, with the military as the leading edge. Dolphins seem to keep parts of their brains awake all the time to control their breathing and come up to the surface while other brain regions are allowed to sleep. Otherwise, they would drown. PET scans of dolphin brains may help to determine how their architecture accomplishes this feat, another aspect of DARPA's PSD program. If those lessons are somehow applicable to human beings, we could see next-generation approaches to long-term wakefulness that rival modafinil, and if those methods are practical and their risks are limited, it will be hard to keep them out of the hands of civilians eager to get an edge in a competitive world.

Suppose that radically altered sleep patterns without threats to health were possible. What would be wrong with that? As Dinges notes, it's a debate we haven't had. The social implications of widespread use of modafinil's descendants would be enormous and difficult to predict. Libertarians would argue that government regulation would be overreaching, conservatives would worry about changing human nature, and liberals would worry about inequitable access to whatever advantages neuropharmacology might confer to those who are already relatively well off. All these views deserve to be aired.

LEANER AND COOLER

The military interest in altering normal biologic patterns to warfighting is hardly new. Longtime Minneapolis residents tell stories about the woozy, skinny young men seen about town during World War II. They were conscientious objectors in sleep and nutrition deprivation experiments. Recently DARPA has been concerned about enhancing soldiers' capacity to go not only without sleep, but without food as well, and even to heal their own injuries. As reported by journalist Noah Shachtman and described on DARPA's Web site, a project called Metabolic Dominance aimed to develop a "nutraceutical," a pill with nutritional value that would vastly improve soldiers' endurance. (I'll confess that when I first saw the phrase "metabolic dominance," it conjured images of some especially odd sexual perversion.) The DARPA Defense Sciences Office explains the goal as "peak soldier performance":

> The vision for the Metabolic Dominance Program is to develop novel strategies that exploit and control the mechanisms of energy production, metabolism, and utilization during short periods of deployment requiring unprecedented levels of physical demand. The ultimate goal is to enable superior physical and physiological performance by controlling energy metabolism on demand. An example is continuous peak physical performance and cognitive function for 3 to 5 days, 24 hours per day, without the need for calories.

One idea is to get the body to switch on call from carbohydrate metabolism to lipolysis, basically relying on stored fats (ketosis) or in other words, a highly efficient Atkins diet but, hopefully, without the risk that too much body fat will be used. That's not a problem for most of us, especially for short periods, but it could create risks for already lean young soldiers if they don't get lots of protein. Presumably, the DARPA program is intended to identify the most rapid results from the combined lipolysis switch and protein load.

When journalist Shachtman bounced the idea of substituting high-nutrition pills for food off some scientists, he got a mixed reaction. The chair of New York University's Nutrition, Food Studies, and Public Health Department wrote in an e-mail to Shachtman that "what this seems to be asking for is fantastic in every sense of the word. Calories are calories, laws of thermodynamics still operate, and humans are still human. I think they should use robots." (Fair enough; as we have seen, they might.) The army has given out grants to see if herbs can enhance endurance and alertness. One candidate is echinacea, a plant that could be added to rations. Another approach is to adapt those nicotine-delivering transdermal antismoking patches to nutrient delivery. The army's Natick Soldier Systems Center has also developed a high-energy meal consisting of three sandwiches, apple sauce with carbohydrates added ("zapple sauce"), and caffeinated gum. Yummy.

This interest in food and supplements may signal the fizzling out of military human enhancement hype. As I have discussed, the Augmented Cognition project faltered at least to the extent that the intrepid moniker has been dropped. The notion of enhancing mitochondria via Metabolic Dominance has been downgraded into a focus on optimizing and maintaining peak performance. Further, Michael Burnam-Fink has reported that the Future Combat System was shelved in 2009. To some extent, the focus has shifted to more mundane, although certainly promising, endeavors. For example, DARPA hosted a workshop in 2010 geared to identifying nutritional biomarkers that can be used to track troop health. As military medical researchers find that troops are too out of shape to handle civilian fitness regimens like Crossfit and P90X, perhaps a back to basics health and fitness focus is more important than grandiose notions of enhancement.

The agency has also invested in ways to see if the body's core temperature can be altered depending on weather conditions. Seriously injured soldiers might be able to go into hibernation while they healed, perhaps after self-administering advanced medication. Already, scientists have put a mouse into hibernation using tiny amounts of hydrogen sulphide, causing life processes to cease for six hours but then reversing the effect seemingly without injury. In principle, the technique could be extended to other mammals. "The ultimate goal," DARPA says, "is to enable superior physical and physiological performance by controlling energy metabolism on demand." A DARPA consultant told *Wired* magazine that "we're asking questions of biochemical processes that have been developed over eons. So there aren't going to be clinical trials tomorrow. But some aspect of this (regulating the body's internal heat) will be here faster than people think."

BUILDING SMARTER SOLDIERS

In his classic *Principles of Psychology* (1890), William James described the marvelous "plasticity" of the brain, referring to its ability to yield to new forces but not entirely. This quality of plasticity allows for the acquisition of new skills. The metaphor has proven to be of enduring value to neuroscience. Recent neuroscience also indicates that as a skill is being learned, the number of neurons applied to it and associated with it gradually decreases, adding a dimension of efficiency to the neural system.

It further turns out that at least one specific chemical in the brain probably inhibits plasticity, so that when it is decreased, learned behavior can be enhanced. NIH neuroscientists have found that when animals are working on new skills, their motor cortex secretes less GABA (gammaaminobutyric acid), and that when they deliberately reduce GABA levels, the neural system is more plastic and the skill can be acquired faster. As Dartmouth's Michael Gazzaniga has pointed out in his book, *The Ethical*

Brain, athletic and musical abilities could theoretically be enhanced by decreasing GABA, but no one knows what the long-term effects of such interventions would be.

Research on enhanced learning is certainly of interest to the military, and DARPA specifically has a project called Accelerated Learning along these lines. "The Accelerated Learning program will develop quantitative and integrative neuroscience-based approaches for measuring, tracking, and accelerating skill acquisition while producing a twofold increase in an individual's progress through the stages of task learning."

Besides learning, another aspect of cognitive capacity that would be of immense value to combat personnel is an improved memory. Battle assignments can be complex and easily misremembered when fast-moving events unfold. Fighter pilots, for example, have to store a vast quantity of information in target-rich environments. One of the companies training monkeys to move a cursor only with their thoughts, BrainGate, formerly known as Cyberkinetics, received DARPA funding reportedly because the agency is interested in increasing the bandwidth of soldiers' brains. The Braingate system is being used in tetraplegics to give them neural control over computer cursors, but it might eventually allow direct human connection to a computer memory and its reservoir of additional RAM for information-dense environments, like urban combat. Katie Drummond reported in *Wired* that in 2009 DARPA solicited proposals for "a system that would optimize human memory storage and recall by synchronizing neural brain waves. . . . Gamma waves facilitate memory creation, and Theta waves turn those short-term recollections into long lasting ones. What Darpa [*sic*] wants is a small, portable system that presents information in an order that would optimally synchronize Gamma and Theta waves."

There are other silicon-based possibilities for memory enhancement. Dubbed a "brain prosthesis," a chip under development is intended to replace damaged parts of the brain. If it works for stroke or epilepsy, it might also be used to enhance normal brains. In memory-impaired people, the hippocampus, responsible for processing experience so it can be stored as memory in other sections of the brain, is often disrupted. An artificial hippocampus has been constructed in rats by electrically stimulating slices of the rat hippocampus and mapping which inputs yield which outputs. The resulting model can be encoded on a chip and placed on the area that needs help. Wires leading from one side of the compromised region to the device and from the device to the other side of the damaged area essentially bypass the compromised circuits. This simple-sounding idea took University of Southern California researchers ten years to accomplish, sponsored by DARPA, the Office of Naval Research, and the National Science Foundation. The USC team is testing its system on slices of rat hippocampus in vitro, and eventually will test it in monkeys to see if it changes behavior that involves memory tasks.

Biology offers other possibilities. Neuroscientists have found a gene that codes for *N*-methyl-D-aspartate (NMDA) receptors in the brain. When they gave adult mice extra copies of a type of NMDA receptor, the mice showed superior learning skills. Genomic and proteomic medicine may make this form of enhancement possible. But would individuals thus "enhanced" then be overloaded with memories, storing vast quantities of detail that are normally ignored because we have evolved to filter out or delete useless bits of information? In *The Mind of a Mnemonist*, the Russian psychologist A. R. Luria describes a patient who could not forget a single detail he had ever experienced. Unable to escape countless particulars, the man had to be trained how to forget; his absolutely retentive memory clogged his ability to pay attention to the present so that rather than appearing brilliant, he seemed timid and slow. Too much memory can literally be maddening, let alone counterevolutionary, unless the effects are short lived. And who would want to volunteer for the first trial?

Thus, the introduction of a new memory storage system and bypassing our evolutionarily developed hippocampus raise the question whether our usual ability to slough off unneeded memories will be threatened, resulting in a cacophony of useless data that could drive one to distraction. Forgetting is often annoying but mostly adaptive, even a great relief. In the film *Eternal Sunshine of the Spotless Mind*, ex-lovers undergo a high-tech brain-erasing procedure to forget about the pain of their breakup. In a literally touching moment in *Star Trek*, Mr. Spock engages in an (unconsented) Vulcan mind-meld with Captain Kirk to help him forget a tragic love affair. Less romantically, undercover agents would benefit from the ability to lose their memories upon capture. Neuropsychologists have already found that deliberate memory loss among victims of parental abuse is both a demonstrable phenomenon (they are not "lying" when they say they don't recall) and a very effective defense mechanism. As the philosopher Bernard Williams has put it, "Forgetting is the most beneficial process we possess."

Experiments with monkeys may not give us the answer to these questions about the effects of a brain chip. The confusion associated with excess memory could result in subjective experiences that are not obvious to observers. There is as well a spectacular potential ethical problem in doing experiments with those whose hippocampus is damaged and can't form new memories: how could one obtain a valid informed consent from people who can't remember what they are doing, or why they are doing it?

Mucking around with memory also raises striking problems with personal identity. Going as far back as David Hume in the eighteenth century, philosophers have noted that our idea of ourselves is intimately bound up with our remembered experiences, including previous ideas about our selves that have entered the stream of consciousness. Anyone who believes that there are certain boundaries that should not be crossed must be concerned about the modification of abilities to remember and to forget. USC's brain chip that would divert electrical charges around damaged brain tissue presents the possibility for some personality change, for example, since a portion of neurons would be disengaged. But Oxford University philosopher Bernard Williams, who specializes in the theory of personal identity, has observed that this situation wouldn't be so different from excising brain tumors, which we have come to accept. Of course, even if the results were the same, the ethics of healing and enhancement could be different.

The artificial intelligence approach to enhancing and complementing natural memory would be more straightforward: engineer a direct connection between your brain and your iPhone. Information could be not only uploaded to the brain but also downloaded to your PDA. DARPA's LifeLog program was a step away. As reported by Noah Shachtman, the idea was to create a database with every communication people have written, all pictures taken of them, and every bit of information about them, and then to use the global positioning system to track all their movements and sensors to record what they say, see, and hear, and add that information to the database. The unfolding events in a potential terrorist's life could be reconstructed in all their dimensionality. But so could yours or mine. The potential civil liberties issues presented by LifeLog got the attention of Congress, policy analysts, and human rights groups and was one of the reasons DARPA's budget was threatened with cuts in 2003. (LifeLog followed the embarrassing revelation of a planned program called Total Information Awareness, in which civilian records were to be used to identify potential terrorists; TIA didn't last long after it was disclosed.)

Citing changing priorities, DARPA quickly dropped the LifeLog project, disappointing artificial intelligence experts who were interested in developing the first models of how people collect and organize their experience. But in fall 2004, a more limited program called Advanced Soldier Sensor Information System and Technology (ASSIST) was created to collect everything a soldier experiences and does in combat. The public relations advantage of ASSIST over LifeLog is that it is limited to a soldier's experience, where privacy isn't a value that trumps information collection and analysis. But it does create a prototype that could have applications for a broader population and set of conditions. Information recorded in the ASSIST program might also be a concern for military lawyers responsible for defending soldiers in courts-martial: Will the data be anonymous? If not, what are the rules for its use?

SMARTER SOLDIERS THROUGH ELECTRICITY

Another approach to enhanced cognitive abilities for soldiers might lie in electrical stimulation of select brain centers. Evidence is accumulating that stimulation of some neurons as an adjunct to traditional rehabilitation can be of value for patients with paralysis. Nobody knows exactly why it works, but doctors at the Rehabilitation Institute of Chicago found that when they implanted electrodes in the motor cortex of stroke victims, they got significantly better results than with standard rehabilitation alone, recovering about 30 percent of lost function compared with 10 percent. Although the approach is not perfect, the gains for people whose arms had for years simply hung at their sides are wonderful. Some stroke patients with speech difficulties experienced improvement in that area, too, even though speaking ability was not the target of the experiment.

An intriguing question is whether electrical stimulation might help uninjured people exceed their normal intellectual capacities. After all, the brain operates on electrical energy. Could people acquire enhanced cognitive skills partly through neurostimulation? One technique being explored is called direct current stimulation or DC polarization. At the 2004 meetings of the Society for Neuroscience, NIH researchers reported that a tiny amount of electricity delivered to the brain through an electrode on the scalp (far less electricity than needed to run a digital watch) can produce measurable improvement in verbal skills. They ran the current through volunteers' scalps and asked them to name as many words as they could that began with a certain letter. The subjects showed about a 20 percent improvement when the current (two-thousandths of an ampere) was running. Since the current ran through the prefrontal cortex, the researchers speculated that the firing rate of neurons was increased, activating cells involved in word generation.

Though the volunteers' concerns about having their brains zapped were relieved after the scientists explained how tiny the charge would be, the associations with "shock therapy" will be hard for many to shake. (In fact, although electroconvulsive therapy [ECT] has acquired a bad reputation, it is often the only treatment that relieves both acute mania and acute depression, as in the case of one of my relatives who has suffered from a bipolar disorder for many years.) But DC polarization delivers a tiny fraction of the charge used in ECT and seems only to leave the subject with an itchy scalp. Of course, the fact that the technique does not involve surgery is also reassuring and makes it more practical than internally implanted electrodes.

Another noninvasive technique is transcranial magnetic stimulation (TMS), in which a magnetic coil is placed above the head and electrically produced magnetic pulses pass through the cortex. Depending on the particulars of the electrical signal that generates the magnetism, these pulses can alter the firing rate of certain neurons. As in DC, there is no pain from TMS, only the sensation of tapping on the skull as scalp muscles contract and a popping sound from the magnetic coil.

The therapeutic hope underlying these projects is of course that they can someday be used to treat stroke patients or those with dementias. TMS seems to be able to target specific brain regions more effectively than DC, but DC appears to carry less of a risk of inducing seizures. And, of course, the long-term effects of frequent exposure to electrical or magnetic stimulation are unknown. Nonetheless, DARPA has given grants to see if neurostimulation can improve impaired cognitive performance and reduce the other effects of sleep deprivation on soldiers, perhaps through helmets that deliver the tiny current. The 2009 NRC report *Opportunities in Neuroscience for Future Army Applications* lists in-helmet and in-vehicle TMS as long-term projects to keep on the R&D radar.

Like so many potentially brain-enhancing technologies, neurostimulation can easily be oversold. Given how much we value cognition, however, even a modest improvement would be considered important. Long-term problems for military personnel might be hard to identify and could seem worth the risk for a marginal gain in mental agility in life-or-death situations. One Chicago scientist, Mark Huang, was quoted in the *Chicago Tribune* as observing that "there are many possibilities that have to be answered ethically. You can use [electrical brain stimulation] in any application where you want to potentially enhance brain function. If you want to learn a new language, potentially the stimulator might help. Would I recommend you do it for that purpose? No. But down the road, who knows? Obviously the sky's the limit and we're still in the infancy stage."

NO FEAR?

Speculative possibilities for “improving” soldiers by altering neural circuits and chemicals are endless and will no doubt be the subject of vigorous scientific, policy, and ethics debates in coming decades. Take another case: managing a gene for fear. A distinguished team of U.S. researchers reported in 2005 that a gene called stathmin, which is expressed in the amygdala, is associated with both innate (unlearned) and conditioned (learned) fear. The team bred mice without the gene (lab animals created without a certain gene are called “knockouts” for obvious reasons) and put them in aversive situations, such as giving them a mild shock at a certain point in their cage training. The normal mice exhibited usual fear behavior by freezing in place, but the knockout mice froze less often. That was the learned fear. When both normal and knockout mice were put in an open field environment, an innately threatening situation, the mice with stathmin spent more time in the center of the field and explored the environment more than the control mice.

Do people with lower levels of stathmin expression exhibit less fear? It’s unlikely that there’s any such one-to-one correspondence in humans, who are far more psychologically complex than mice and capable of modifying their genetically programmed behavior. Yet one can imagine that some imaginative military official who overestimates the importance of genetic information will someday propose screening Special Forces candidates, or even raw recruits, for the “fear gene.” That someone would have this bright idea is not at all far-fetched. A few years ago, the Burlington Northern Santa Fe Railway Company had to pay $2.2 million to employees who had been secretly tested for a gene associated with carpal tunnel syndrome, even though the scientists who developed the test said it couldn’t work for that purpose. The company was trying to see if the workers’ medical claims were due to their jobs or their genes.

If DNA testing for a fear gene is both scientifically and ethically dicey, what about setting out to create people who lack that characteristic? Would breeding humans without stathmin or any other genes associated with fear reactions in lab animals create more courageous fighters? That this conclusion would be a huge leap from animal studies might not stop some parents who harbor ambitions for a child capable of a glorious military career, or just don’t want to give birth to a “sissy.” Might parents also consider raising children without intestinal bacteria, or even more worrisome, with optical fibers implanted in their brains? Trouble is, fear or its functional equivalent is again one of those ancient properties exhibited by just about every animal. It surely has tremendous survival value so that its removal would be deeply counterevolutionary and would almost certainly generate numerous unintended and undesirable consequences for the individual, let alone thrust us headlong into a fierce debate about whether enhancing the human has gone too far. I'll have more to say about that looming question after we cover some more territory that illustrates some neuroscience-based options for enhancement, with military applications leading the way.

Optogenetics also holds promise for controlling the fear response. As discussed in a previous chapter, Stanford researchers have engineered mouse neurons to be photosensitive, such that particular neural circuits in the amygdala can be controlled with fiber optics. According to the Stanford scientists, the illuminated mice "scampered freely across an open space," displaying the same confidence (or naïveté) to brave an inherently threatening situation as the stathmin-free mice.

Research on the microbiome (our countless gut-flora friends) is also generating fascinating glimpses of fear and anxiety. Sven Pettersson and his team have shown that intestinal bacteria significantly shape brain development and adult behavior. As described by science writer Robert Martone,

> The scientists raised mice lacking normal gut microflora, then compared their behavior, brain chemistry and brain development to mice having normal gut bacteria. The microbe-free animals were more active and, in specific behavioral tests, were less anxious than microbe-colonized mice. In one test of anxiety, animals were given the choice of staying in the relative safety of a dark box, or of venturing into a lighted box. Bacteria-free animals spent significantly more time in the light box than their bacterially colonized littermates. Similarly, in another test of anxiety, animals were given the choice of venturing out on an elevated and unprotected bar to explore their environment, or remain in the relative safety of a similar bar protected by enclosing walls. Once again, the microbe-free animals proved themselves bolder than their colonized kin.

The basic science is remarkable, but perhaps we have nothing more to fear than no fear itself. This is one area where international consensus among twenty-first century professional military organizations might well be reached. Already one group of military and science thought leaders has concluded that there are many reasons to ban the applications of fear-managed neurotechnologies. The U.S. Naval Academy's 2010 McCain

Conference report noted that "[a]ltering soldiers' levels of fear and aggression may expose soldiers, their missions, and society in general to increased risk of injury or death," recommending the "prohibition of alteration of fear or aggression levels, inasmuch as these severely inhibit the exercise of individual free will, and consequently endanger missions, citizens, and the relationship between citizens and their soldiers."

EASING EMOTION

The amygdala is an ancient organ that is critical to emotionality and memory. If the amygdala is damaged or removed, people may lose the ability to interpret cues from others that are intended to convey emotions such as anger. And it triggers release of the hormones epinephrine (also known as adrenaline) and norepinephrine into the bloodstream, which help emotionally weighted images to become firmly entrenched in long-term memory. All of us are quite familiar with the subjective experience, well described by the neuroscientist James McGaugh of the University of California–Irvine: "Whatever is being learned at the time of emotional arousal is learned much more strongly. . . . Any strong emotion will have that effect. It could be winning a Nobel Prize. It could be a very faint whisper in the ear, 'I love you,' at the right time."

If the amygdala's hormone-releasing processes could be inhibited, the searing of bad experiences into memory might be reduced. There is some evidence that beta-blockers, commonly used to treat heart disease, also have the ability to block neurotransmitters that consolidate emotion with long-term memory. Irvine researchers showed one group of volunteers a slide show that told a prosaic story about a boy and his mother. A second group was shown the same story except that the boy was hit by a car and his legs amputated. The members of a third group were shown the second, emotional story after taking a beta-blocker. When their memories were tested three weeks later, the drug group had flat emotional responses, similar to the group who had seen the uneventful version of the boy's outing with his mother.

A Harvard study of trauma victims had similar results. Some were given the beta-blocker propranolol; the others, a placebo. After a month of psychological counseling, scores on a post-traumatic stress disorder scale were lower for the beta-blocker group, but not significantly. However, after three months, 40 percent of the placebo group members had elevated physiological responses when they were asked to recall their traumatic experiences whereas none of the propranolol recipients did. With these experimental results as a clue, clinical trials of propranolol to prevent the chronic effects of traumatic experiences are already under way and show promise. Although the long-range burden of post-traumatic stress disorder for combat veterans is not strictly speaking a military concern, veterans and their families could be among the beneficiaries of effective drug therapy.

Neuropsychiatrists disagree about whether the promising results of early studies indicate that memories are being erased or that they are being bracketed so that they can be more easily handled by the sufferer. Whatever the actual mechanism, the therapeutic benefits of relieving painful memories are obvious in the case of people who have experienced trauma, such as combat veterans or the victims of sexual abuse. Those directly affected by terrorism, who psychiatrists say normally have a very poor psychological prognosis, could also enjoy relief. And who among us wouldn't prefer to be relieved of painful memories of terrifying accidents or the dull ache when we reach the anniversary of the deaths of those we have loved and prematurely lost?

But there are deep philosophical and perhaps sociological reasons that the use of these medications should at the very least be highly regulated. In its report *Beyond Therapy: Biotechnology and the Pursuit of Happiness*, the President's Council on Bioethics, which had studied the possible uses of propranolol in psychiatry and the implications of its wider use, raises some disturbing questions:

> Would dulling our memory of terrible things make us too comfortable with the world, unmoved by suffering, wrongdoing, or cruelty? Does not the experience of hard truths—of the unchosen, the inexplicable, the tragic—remind us that we can never be fully at home in the world, especially if we are to take seriously the reality of human evil? Further, by blunting our experience and awareness of shameful, fearful, and hateful things, might we not also risk deadening our response to what is admirable, inspiring, and lovable? Can we become numb to life's sharpest sorrows without also becoming numb to its greatest joys?

The council's final judgment on the prospect of widespread use of drugs to blunt disturbing memory, a world with only happy memories, is worth pondering:

> To have only happy memories would be a blessing—and a curse. Nothing would trouble us, but we would probably be shallow people, never

> falling to the depths of despair because we have little interest in the heights of human happiness or in the complicated lives of those around us. In the end, to have only happy memories is not to be happy in a truly human way. It is simply to be free of misery—an understandable desire given the many troubles of life, but a low aspiration for those who seek a truly human happiness.

Soldiers and others who suffer from depression, insomnia, and other disorders following their traumatic battlefield experiences likely wouldn't find these philosophical reservations very convincing. Their concern, and that of their loved ones, is to reduce the torment of daily life. Nonetheless, it's worth considering the implications of these medications for the military before they are routinely included in field packs. Soldiers who could pop an antiguilt pill might not accrue experiences that lead them to hesitate when faced with an enemy they have been trained to annihilate. But military physicians have expressed appropriate concern about the force that might be produced by such a drug. My old friend and colleague Edmund Howe, who directs the medical ethics program at the Uniformed Services University of the Health Sciences in Bethesda, Maryland, and holds degrees in psychiatry and law, told New York's *Village Voice*: "If you have the pill, it certainly increases the temptation for the soldier to lower the standard for taking lethal action, if he thinks he'll be numbed to the personal risk of consequences. We don't want soldiers saying willy-nilly, 'Screw it. I can take my pill and even if doing this is not really warranted, I'll be OK.' If soldiers are going to have that lower threshold, we might have to build in even stronger safeguards than we have right now against, say, blowing away human shields. We'll need a higher standard of proof [that an action is justified]."

Other promising treatments, however, may not suffer the same ethical issues as prophylactic memory dampeners like propranolol. In conjunction with the Multidisciplinary Association for Psychedelic Studies (MAPS), Michael Mithoefer completed a study in 2008 demonstrating the therapeutic benefits of MDMA, or ecstasy, on PTSD patients. According to MAPS executive director Rick Doblin, "MAPS and Mithoefer's major breakthrough showed that over 80 percent of the subjects in the MDMA group no longer qualified for diagnosis of PTSD, as compared to 25 percent in the placebo group. . . . An even more important breakthrough, which we are currently working to write up in a scientific paper, is from the results of our long-term follow-up evaluations of the subjects, administered at an average of 41 months post-treatment. We found that, on average, the subjects have actually gotten a bit better over time, demonstrating that MDMA-assisted psychotherapy has lasting benefits."

Recent advances in brain scanning may shed light on the neurological underpinnings of PTSD. Using magnetoencephalography (MEG), researchers have been able to identify the neuroelectrical correlates of PTSD with 90 percent accuracy. This could be a boon for early diagnosis because behavioral symptoms can take years to manifest. Other findings indicate that morphine injections can lessen the likelihood of developing PTSD if administered shortly after sustaining a traumatic injury. Researchers do not know if this results from morphine's anesthetic properties or if it affects the formation of memory, but it holds promise in the search for a "morning after pill" for PTSD.

DARPA's interest in PTSD has recently led to studies of a wide range of treatment modalities. In 2008, *Wired*'s Noah Shachtman reported that "The Army just unveiled a $4 million program to investigate everything from 'spiritual ministry, transcendental meditation, [and] yoga' to 'bioenergies such as Qi going, Reiki, [and] distant healing' to mend the psyches of wounded troops." The Pentagon has also funded the development of electronic devices that track PTSD patients' movement and health status, feeding the information back to medical centers and prompting the patients with assistance.

DARPA's Enabling Stress Resistance program seeks to discover the neurological effects of stress via cutting-edge "advances in molecular neurobiology, neuroimaging, and molecular pathway modeling." After understanding the physiology of stress, this project is intended to develop "cognitive, behavioral, and pharmacological interventions that will prevent the deleterious effects of stress on warfighters. " DARPA is also developing a new neuroimaging technique called Quantum Orbital Resonance Spectroscopy (QORS) that combines "recent advances in quantum photonics with Magnetic Resonance Imaging and Spectroscopy." QORS is intended to revolutionize neurodiagnosis of PTSD and traumatic brain injury. On the pharmacological front, the National Research Council's 2008 report notes the high value of nanotechnological drug delivery systems "that allow drugs to cross the blood-brain barrier, increase the precision of delivery, evade immune system defenses, evade metabolism, or prolong actions at cellular or downstream targets . . ." They could also facilitate the use of brain proteins themselves as drugs.

LEARNING FROM OUR ANIMAL FRIENDS

Neuroscience isn't limited to human brains and nervous systems, of course. DARPA spokeswoman Jan Walker was quoted in *Mother Jones* magazine (no friend of DARPA to be sure) concerning the agency's interest in what can be learned from the sensory abilities of nonhuman animals: "We're interested in investigating biological organisms because they have evolved over many, many years to be particularly good at surviving in the environment . . . and we hope to learn from some of those strategies that Mother Nature has developed." In the same article, a DARPA project manager added that "inspiration from nature . . . will allow more life-like qualities in the system."

A 2001 report by the National Academy of Sciences (NAS) on new opportunities in biotechnology and information technology described several DARPA initiatives that reflect this principle of learning from nature. One is called the "electronic dog's nose," attempting to understand how dogs' neurosensory processes are able to detect explosives and use that information to develop a model for electronic bomb sniffers. Besides modeling artificial systems based on animals, there's also the possibility of altering the animals themselves. A type of wasp larvae can be exposed to certain vapors so that when it matures it detects explosives or "odors of interest." Another idea is to install electronic chips in insects "so that their hunting patterns become search algorithms for DoD sensors," in the words of the NAS report. Evolution has taught insects the most efficient ways to scan their environment, techniques that could be useful in the design of human sensing systems. Other non-neuroscience animal-inspired DARPA projects include studying how geckos climb walls, how octopuses hide, and how various critters employ adaptive camouflage.

Studying the perceptual systems of other animals will not only stimulate new designs for sensing devices to aid human operators, but will also lead some to wonder about the feasibility of introducing genes or proteins to modify human beings. We already introduce biological materials of other animals into the human body (vaccines, porcine valves for hearts), and are already going down the road of genetic modification of prospective children (prenatal testing and screening, genetic engineering), so why not consider putting genes in adults as well? As is generally the case when national security is at stake, risks to the recipients are likely to be assessed differently than they would be in the normal context of medical care or research. But should they be? Thus, we are once again led to ethical issues in enhancement technologies.

THE ETHICS OF ENHANCEMENT

Should we build better soldiers through "artificial" enhancements? Is there even a valid distinction to be drawn between artificial and "natural" enhancements such as exercise and discipline? Aren't we just trying to gain whatever advantages we can as nations have always tried to do, or are these techniques cheating nature? Can we manage the consequences, or are the risks for the individual and for our society too great? These questions are part of a raging debate about whether we should use new discoveries in neuroscience and other fields like genetics to improve ourselves, our descendants, and perhaps even the species. If it would be acceptable to enhance civilians, then it's hard to see why national security agencies should be barred from giving warfighters an edge. If it's not acceptable to enhance civilians, there still might be a special case to be made for tuning up soldiers, but the argument for a military exception will need to be a powerful one. So the more general enhancement debate is important for the idea of building better soldiers.

There are special features of the enhancement debate in the military context. Under normal circumstances, individuals can of course refuse to do things that other people think will "improve" them. Workers and students can decline to accept enhancements that their employers or schools recommend, perhaps at the cost of losing their positions. But military personnel might not have that privilege. According to the Uniform Code of Military Justice, soldiers are required to accept medical interventions that make them fit for duty. Writing on a grant from the National Science Foundation, the authors of a 2009 study on the ethics of human enhancement appreciate the problem: "In the military, soldiers have fewer rights than civilians; they lose freedoms and have to obey reasonable orders. Of course, that is the issue: Is it reasonable for the military to require enhancement of soldiers beyond their usual training?"

Experimental treatments might be acceptable under extreme combat conditions if there was a serious threat and no reasonable alternative to protect the force. The U.S. government has shown a tendency to defer to commanders in a combat situation if they think some treatment is likely to do more harm than good, even if unproven. An example is the use of the anthrax vaccine during the 1991 Gulf War, though it had not been shown effective for inhalational anthrax in humans. Of course, vaccination is not normally thought of as an enhancement so much as a protection. And as Evan DeRenzo and Richard Szafranski observed in an *Air Force* magazine article on the ethics of human performance enhancement in the military, freedom-of-choice arguments have more traction in an all-volunteer army than in a force of draftees.

I trace the modern debate about the general ethics of enhancement to an esoteric discussion that took place in the pages of philosophy of medicine journals in the 1970s. The issue was the meaning of health and disease, two concepts that are very familiar but surprisingly hard to pin down. What exactly does it mean to be healthy or sick? There seemed to be general agreement that the concepts of health and disease turned on the idea of normalcy. Some argued for a statistical sense of normalcy, others for the notion that to be normal is to be capable of "species typical functioning" with regard to survival and reproduction. No refinements seemed able to avoid the fact that the ideas of health and disease (literally "dis-ease") are useful intuitive guideposts but not very precise; nor are the concepts of treatment and enhancement. Take the example of advanced sleep medication for males in their forties, a time of life when many men experience disrupted sleep patterns. Assume that some degree of insomnia is typical for human males beginning in their fourth or fifth decade. Is Ambien a *treatment* for a sleep disorder or an *enhancement* to sustain a more youthful sleep schedule?

The enhancement debate picked up steam in the 1990s with the spread of drugs like Ritalin and Prozac; then, the steroid scandal in sports and the erectile dysfunction treatment craze made the issue nearly inescapable. On one extreme are the transhumanists, a philosophical movement populated by scientists, philosophers, futurists, and others that has grown in recent years with national meetings and publications. The leading transhumanist writers call explicitly upon neuroscience to depreciate the boundaries between treating disease and enhancing the individual. In *More Than Human*, Ramez Naam cites work on computer chip neural implants as an example of the emerging capacity to go well beyond healing the sick to vastly improving what are thought of as normal capacities. Computer hardware outside the body's boundaries will be unnecessary, according to Naam, as implants will enable us to Web surf, send e-mails, and enjoy far more powerful sensations simply by intending to do so. In *The Transhumanist FAQ*, Nick Bostrom similarly contends that human evolution is still primitive, "that the human species in its current form does not represent the end of our development but rather a comparatively early phase." We as a species can alter ourselves by the technology we have created, and that very technology "will eventually enable us to move beyond what some would think of as 'human.'" That posthuman or more fully human creature will be perpetually young and healthy and vastly more capable of experiencing love, beauty, and tranquility than are we. Ultimately, we will be able to upload our very selves to new bodies as needed or desired, having downloaded all the contents of our mind to hugely powerful computers with multiple backups to ensure the self 's immortality.

On the other side of the enhancement argument are many neoconservative thinkers like Francis Fukuyama, a political philosopher who was a member of President George W. Bush's Council on Bioethics. The council published the report I quoted earlier called *Beyond Therapy* that expressed reservations about memory control. The report also expressed skepticism about the enthusiasm of many Americans for any drug or device they can get that seems to offer easy self-improvement. Fukuyama is about as upset as he can be about the unbridled enhancement philosophy of the transhumanists. In a 2004 article in *Foreign Policy* magazine, Fukuyama called transhumanism the world's most dangerous idea. Transhumanism seems reasonable "when considered in small increments," Fukuyama writes, which is exactly what makes it so dangerous. "It is very possible that we will nibble at biotechnology's tempting offerings without realizing that they come at a frightful moral cost."

In his book *Our Posthuman Future*, Fukuyama expresses two main worries about the transhumanist goal. First, if we ever succeed in creating beings with far greater abilities than ourselves—through biotechnology or genetics or neuroscience or whatever—political equality will be jeopardized. By tinkering with our essential human nature, the universal essence of humanity will have been changed, and with it the rational basis for thinking of all persons as equal in the political system. Second, the intricate human being created through millions of years of evolutionary selection is carefully balanced between, for example, violence for self-defense and affection for social cohesion, and deliberate interventions are unlikely to achieve creatures with just the right blend of good and bad qualities. Nor can we necessarily discern what those qualities are, as they have to prove themselves in the complexities of social life with its countless variables.

I find myself squarely in the middle. I'm not as sanguine about a hyper-enhanced future as the transhumanists, nor am I comfortable with their utopianism. As David Hume wisely observed, the future tends to resemble the past. We can expect a range of consequences as we incorporate new technologies and instrumentalities into our lives and bodies. I also have doubts about the metaphysics of the idea that the subjective experience of personal identity can ever be captured, even by the most comprehensive memory chip. But neoconservatives such as Fukuyama seem to me to harbor an excessively dour view of the technological future. First, I'm not as convinced as he is that the idea of human equality is grounded in a universal concept of essential human nature; my more pragmatic view has it that human equality is a rather squishy moral notion. It feels right to most of us, and we rally around when we need to. Second, there is plenty of room for argument about his view that human evolution has produced a mix of good and bad qualities that can't be improved upon. Still more fundamentally, I can't swallow the suggestion that, in a world of ethnic and religious tension, nuclear proliferation, global warming, emerging infections, and terrorism, transhumanism is our biggest problem.

Where I do emphatically agree with Fukuyama is that the proper response to transhumanism is not to prohibit research and development of these new technologies but to develop careful monitoring and regulatory systems. Some of this can be accomplished by the scientific community and its organizations. For example, in 2005 a committee that I cochaired recommended guidelines on human embryonic stem cell research. The committee was created by the National Academies, an organization of elected members that is chartered by the federal government to advise it on science, medicine, and engineering issues. Because the Bush administration allowed research funding for only a few human embryonic stem cell lines, scientists weren't sure what research would be considered appropriate, especially since several states and private companies intended to do work involving this controversial field. Among many other recommendations, our committee concluded that no human embryonic stem cells should be placed into nonhuman primates at any stage of development. Part of the concern is that some of the human cells might turn into brain cells in, say, a rhesus monkey embryo, and they might contribute in an organized way to the monkey's brain. Although we can't know if the monkey's brain would be changed by the human cell contribution, we also can't be sure it wouldn't be. Would any resulting creature feel like a human "locked" in a monkey's body? While highly unlikely, this possibility arguably carries a serious ethical burden. For similar reasons, we also recommended against putting embryonic stem cells from other animals into human embryos.

Given the publicity and sensitivity of the embryonic stem cell issue and the prestige of the National Academies, we felt sure our recommendations would be adopted by legitimate research centers and individual scientists.

But that voluntary arrangement falls well short of government regulation. Also, with regulation there often comes significant government funding for research, which acts as an important incentive to follow the rules. We have seen how important government funding is in keeping a new area of medical science on track in the case of in vitro fertilization. When the Reagan administration decided to stop funding for IVF research in 1980, the emerging industry was cut loose without public scrutiny. The result was what many consider to be a field that bears a resemblance to the Wild West, with all sorts of practices pursued and claims made and with only limited public scrutiny and modest (and relatively recent) self-regulation.

National security research on enhancement technologies will require the close involvement of advisory bodies of people both in government and outside it, with as much transparency as possible and, when transparency must be limited, with whatever security clearances are needed to make full participation possible. While some general principles should be articulated and become part of our regulatory framework, much of the hard work will have to be done on a case-by-case basis. There are some models out there for ethical review in security policy that I will talk about in the last chapter. The ethics of enhancing warfighters' capabilities with emerging neurotechnologies needs to be moved onto our national policy agenda.

In addition to reactive regulatory mechanisms, some thinkers propose proactive measures to mitigate the potential harms of human enhancement. Julian Savulescu and Ingmar Perrson, for example, argue that technological development has always exacerbated the relative ease of causing harm relative to that of benefit, and transhumanism is no exception. Technological development has already made it possible "for small groups, or even single individuals, to kill millions of human beings" with nuclear and biological weapons. Transhuman endeavors like cognitive enhancement may exponentially speed up the feedback loop between scientific discovery and application by making researchers and DIY biopunks smarter and smarter. Short of enacting a totalitarian surveillance state, the authors state that a fundamental improvement of morality is required to avert the destruction of ourselves and the environment. Perhaps transhumanism could be turned back on itself—that is to say, the augmentation of morality could enhance the way we think about enhancement and progress in the first place. But is the biotechnological enhancement of morality even possible?

Bioethicist Michael N. Tennison suggests that the moral enhancement community look into recent research on mirror neurons and psychedelics for inspiration. Mirror neurons have been shown to sympathetically imitate those of an observed subject: Studies of monkeys by Marco Iacobini and colleagues demonstrate that neurons fire not only when the animal "performs goal-oriented actions," but also when it "observes somebody else performing these actions." These results have been preliminarily corroborated in human subjects, and is theorized to form the basis of intersubjectivity, sociality, empathy, and morality. Could a biotechnological augmentation of the mirror neuron system enhance morality?

Alternatively, recent research suggests a connection between the psychedelic experience and persisting altruistic outlooks. In a study of the South American shamanic psychedelic *ayahuasca*, a single experience of the brew appeared to have lasting effects. A study by Stephen Trichter et al. purported to show "that those who drink ayahuasca on just one occasion . . . tend to, after their experience, be more empathic and feel more connected to others. . . ." Similarly, Roland Griffiths of Johns Hopkins University conducted a double-blind study comparing the effects of psilocybin, a psychedelic, and methylphenidate, a stimulant, in subjects with no prior hallucinogen experience. Fourteen months later, he followed up with the subjects of this study, reporting that "The most striking finding from this 14-month follow-up evaluation . . . is that a large proportion of volunteers rate their 'psilocybin experience' as among the most personally meaningful and spiritually significant of their lives. . . . Compared with methylphenidate, attributions to the psilocybin experience also included positive changes in attitudes, mood, altruism, and other behaviors." Could the use of psychedelics, or a biotechnological imitation of their neurological effects, constitute a type of moral enhancement?

The implications of moral enhancement for the military are fascinating: Would a morally enhanced warfighter be better equipped to distinguish an enemy from a noncombatant? Would it help align foreign policy with just war theory? Would an enhanced sense of empathy actually increase the psychological trauma of killing, or prevent one from being able to kill at all? In the words of a 2009 National Science Foundation-sponsored study of human enhancement, "[m]ilitary applications of human enhancement technologies presents an even trickier moral and social dilemma [than outside the military]: Should we be in the business of weaponizing or modifying humans for someone else's ends, specifically to inflict harm on others or otherwise better prosecute a war . . . ?"

Perhaps the targets for enhancement should not be the warfighters themselves but those who bear the heavy moral responsibility for putting others in harm's way. In that case our leaders might take to heart the example of the befuddled and decidedly unenhanced President Merkin Muffley (played by Peter Sellers) in Stanley Kubrick's dark classic, *Dr. Strangelove* (1964). Faced with a row in his top-secret bunker between a high-ranking officer and the Soviet ambassador he admonished, "Gentlemen, you can't fight here! This is the War Room!"