Science Fact

Human 2.0: Being All We Can Be
Part II

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In the opening half of this article on reengineering humanity (in the Jan/Feb 2016 issue), we reviewed eugenics, genetic therapies, and a variety of physical treatments and enhancements. In this concluding segment we'll consider a yet more ambitious prospect: changes that, in coming years, we might see made in, and to, the human nervous system—even involving the brain itself.

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Neural prostheses

Like the rest of the human body, the nervous system is prey to impairments—some of which can already be mitigated with electronics.

Implanted electronic devices can alleviate hearing loss due to certain types of damage to the cochlea (inner ear), bypassing damaged auditory hair cells to directly stimulate the auditory nervous system. Hundreds of thousands of people worldwide (and the hero of Jay Werkheiser's 2015 novelette "Usher"[1]) have had a degree of hearing restored with cochlear implants.

Remember Lt. Geordi La Forge of *Star Trek: The Next Generation,* blind without his bionic visor? Visual prostheses are already here. One such device is an option for people with damaged retinas but functioning optic nerves, for example, those afflicted with macular degeneration or retinitis pigmentosa. Cameras wirelessly transmit imagery data to retinal implants (electrode arrays implanted at the back of the eye); the implants, in turn, stimulate the surviving retinal cells.

Although the FDA approved the first retinal implants in 2013, their adoption remains limited—perhaps because the implants' capabilities are so limited. Their resolution is low, beneath the 20/200 visual acuity threshold by which the AMA defines functional blindness. (With 20/200 vision, a person can read from a distance of 20 feet only what a normally sighted person can read across a distance of 200 feet.) Further, these implants do not yet support color vision.

The viewing angle they offer is highly restricted, amounting to "tunnel vision." In principle, however, nothing precludes the development of larger, more sensitive, implantable electrode arrays that would restore a greater degree of eyesight.

In a related approach, researchers have recently implanted infrared-sensitive photodiodes into the eyes of blind rats. Special eyeglasses project IR images onto the photodiode array, which stimulates neurons beneath the nonfunctioning retinal surface. To date, this technology, too, remains monochromatic and available only at resolution levels still consistent with legal blindness.[2]

A second type of visual prosthesis transmits data to electrodes implanted directly into the brain, more specifically, the visual cortex.[3] By bypassing the optic nerve, such prostheses can treat categories of blindness that retinal implants cannot.

The image feed for all these visual prosthesis comes from glasses-mounted cameras. A sufficiently miniaturized camera might someday sit within the eye socket—a true bionic eye.[4]

In theory, the data fed to visual implants could come from any source, including distant sensors—not limited to visible-light wavelengths—and even computer-synthesized imagery. (Maybe Superman's X-ray vision isn't *entirely* silly.)

Other neural prostheses address nonsensory conditions. Similar to a pacemaker electrically stimulating a diseased heart to regulate heartbeat, deep brain stimulation (aka the "brain pacemaker") delivers electrical pulse sequences through precisely implanted electrodes to regulate selected activities within the brain. DBS technology was developed to interrupt the tremors of early-stage Parkinson's disease, a degenerative disorder of the central nervous system. DBS now helps more than one hundred thousand Parkinson's patients. DBS technology is being researched for treating an array of psychiatric conditions, including depression, obsessive-compulsive disorder, and posttraumatic stress disorder.[5]

(Perhaps electrodes implanted into the brains of the cyborg Daleks of *Doctor Who* explain their emotion-ectomies.)

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Of all the nerve

Nor is the potential for treatment by neural implants limited to conditions of the central nervous system. The FDA recently approved Maestro, aka the "appetite pacemaker." Maestro is implanted into the abdomen to interrupt hunger pangs by interacting with a branch of the vagus nerve. Maestro doesn't address overeating arising from (for example) poor dining habits.[6]

But vagus nerve stimulation (VNS) seems poised to offer far more than appetite suppression. The vagus (Latin for wandering) nerve, connecting many organs in the chest and abdomen with the brain stem, has been likened to a backdoor for hacking human physiology. The vagus nerve terminates in a brain subsystem called the nucleus tractus solitarius, which in turn connects with several neurotransmitter-producing regions of the brain. Neurotransmitters, of course, are the biochemical molecules that intermediate many neurological processes.

VNS has been tested in connection with medical conditions as varied as depression, epilepsy, migraines, tinnitus (ringing in the ears), Crohn's disease (an inflammation of the gut), rheumatoid arthritis (an autoimmune inflammation of joints), and rehabilitation from strokes.

Traditional VNS involves implanting an electronic pulse generator in the patient's chest—an expensive and intrusive surgical procedure. An inexpensive device now under trial would provide VNS simply by pressing a handheld stimulator against the neck. Putting the patient into the control loop isn't always appropriate—an epilepsy attack, for example, may strike with little warning. For other conditions, however—migraines, say—patients may have ample opportunity to self-treat. Through patient-specific software loaded into a VNS device, physicians can control the number and frequency of VNS applications, comparable to writing prescriptions for a limited number of pills. British pharma giant GlaxoSmithKline calls the technology *electroceuticals*.[7]

Tweaking the human brain . . . what could *possibly* go wrong?

The "wireheads" of Larry Niven's Known Space—addicted to the direct electrical stimulation of their neurological reward circuits—suggest one potential problem. In Michael Crichton's

1972 novel (and the basis of the 1974 movie) *The Terminal Man*, a brain implant intended to control seizures goes horribly wrong. Less dramatic, but also cautionary, consider (likewise not specifically VNS-related) Ian Creasey's "Pincushion Pete" and Marissa Lingen and Alec Austin's collaboration "Potential Side Effects May Include."[8]

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Misty (and not always) water-colored memories

Neuroscientists are also unraveling the secrets of biological memory. Our memories are at the core of who we are—and yet, specific memories can torment us. MIT researchers have already inserted a memory into, and reprogrammed a memory of, genetically reengineered mice.[9, 10] This line of research might, someday, offer treatments for posttraumatic stress syndrome (PTSD). Or, as Philip K. Dick had it, implanted memories might substitute for tourism. His 1966 story "We Can Remember It for You Wholesale," has already served as the basis of two *Total Recall* movies.

DARPA initiated the Restoring Active Memory (RAM) program to investigate prostheses to treat memory loss from traumatic brain injury. One aspect of RAM involved patients previously fitted with intracranial electrodes for the study of their epilepsy. In a 2012 experiment, electrical stimulation of the entorhinal cortex (a region of the brain located between the neocortex and the hippocampus) was shown to enhance memory formation and recall. To leverage future developments, another part of the RAM program is developing implantable microelectrode arrays (aka, "memory chips").[11]

As the United States's BRAIN (Brain Research through Advancing Innovative Neurotechnologies) initiative and the European Human Brain Project expand our knowledge of the brain's detailed workings, the types of neural prostheses and the functions they can perform are only apt to grow.

* * *

Mind over keyboard

Keyboards and displays seem so twentieth century. If a brain/machine interface (BMI) may someday control prostheses, why not also use a BMI to control computers? Why not think commands at a computer? Why not receive responses by direct stimulation of the visual or auditory cortexes?

Presuming an OFF switch and a Really Good Firewall, wouldn't a neural interface to the Internet be awesome?

We often use "computers" as much to communicate with one another as to compute. Why not use BMIs to connect brain to brain? There has, in fact, been a proof-of-concept demonstration of telecommunications linking two minds: EEG/Internet/EEG. One headset wearer saw a videogame screen, but could only *think* about firing at the game's targets. The remote participant, with only his EEG headset to provide second-hand game status, had control over firing at unseen targets. For this simple task, firing accuracies as high as 83% were reported.[12, 13] This is hardly technology-enabled telepathy—but give the engineers time.

Someday, perhaps, we will have thought-controlled interfaces. Perhaps a much-improved EEG will suffice, and we'll go online by wearing special helmets or headsets. Ben Bova's short story "The Next Logical Step" upgraded an EEG-based helmet with neural stimulation, for a fully immersive virtual-reality experience.[14] Craig Thomas's 1977 technothriller *Firefox* (the basis of the 1982 movie) involved a fighter plane with thought-fired weapons controlled with helmet-mounted sensors. A sensor-lined BMI helmet was also a premise of my 2002 story "Survival Instinct."[15]

For the most capable BMIs, we may need to go inside the skull, the better to sense the faint electrochemical signals of specific neurons. That seems likely to involve many tiny implanted electrodes, successors to research we've already overviewed—*not* massive spikes jammed into the brain à là the 1999 movie, *The Matrix*. The ideal solution, of course, is a neural interface so compact it can be delivered without surgery. Ramez Naam's 2012 novel *Nexus* gets a BMI inside the brain sans surgery in a dose of a nanocomputer-based "drug."

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An SF author (and physicist and computer engineer) predicts

Having conveniently assumed in several of my stories that high-capability neural interfaces and BMIs will eventually become practical, last year I found myself on a panel at an academic conference discussing, among other topics, future implications of nanotech. That (and thirty years working as a system developer) finally got me to think deeply about how neural implants might someday be built. My conclusion: within a few decades, BMIs will be *grown* inside the brain.[16]

- The electrodes will be carbon-fiber arrays, thin enough to wind their way among the most tightly packed neurons. Our cells grow microtubules only a few nanometers across; surely nanotechnologists will learn to mimic the process.[17]
- The implant's growth process, and later the manipulation of data streaming from/to the electrodes, will be managed by a nanotech-enabled computer small enough to put inside the skull without surgery (the skull has natural gaps through which nerve bundles pass).
- A few of those grown-in-place electrodes will serve as a radio antenna. The BMI's radio connection can be very low-powered; it need only link with the cell phone (or other wireless gadget) in one's pocket, purse, or bracelet.
- The implant will be fueled, just as our neurons are, by the glucose naturally circulating in cerebrospinal fluid.
- Carbon atoms recovered from glucose (and/or other organic molecules in the cerebrospinal fluid) will be used to grow those carbon fibers.
- The human brain runs on about twenty watts of power; the bit of power to be siphoned off to operate a BMI is trivial by comparison.[18]

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Entirely out of one's mind

Might some disabled individuals choose to relocate *completely* into a sufficiently lifelike robotic body or a virtual environment? If not the disabled, how about the dying?[19]

Let's begin with transplantation into a robot. Given a high-quality BMI, such a cyborg would require life support only for the transplanted brain. As it happens, the human brain is already significantly isolated from the rest of the body. The brain sits behind the blood-brain barrier (the selectively permeable barrier that separates the circulatory system and the central nervous system), taking nourishment from, and depositing metabolic byproducts into, cerebrospinal fluid. "Brain support" wouldn't be any more complex than full-body life support, and might be simpler.

Our brains don't merely think deep thoughts. Large parts of the brain process sensory inputs. The hypothalamus regulates our autonomic nervous system (which, in turn, directs our internal organs) and controls the secretions of our endocrine system. The brain also controls voluntary muscular actions and reacts to hormonal inputs. What would happen to a brain divorced from the body, denied these non-cerebral tasks? We don't know.

Rather than transplant a *brain,* perhaps we can avoid dealing with those messy, unthinking parts by instead transplanting the *mind*.

Cognitive research has yet to establish what, exactly, a mind is. The common supposition is that self-awareness and memories reside—somehow—in the brain. If we can copy thought and memory patterns into a computer, then—perhaps—we can relocate the essence of a human mind. In 2012, Russian media mogul Dmitry Itskov set out to have such technology within a decade. A year later, well-known futurist Ray Kurzweil forecast that copying of a human mind could be done in a more conservative four decades.[20]

Whether looking out one decade or four, the goal remains aspirational. The human brain is comprised of about one hundred *billion* neurons; together, they form a mesh of (as a conservative estimate) one hundred *trillion* or more synapses.[21] Thought, memory, and self-awareness take place, in ways still far from understood, within the synapses of the brain. To copy a mind and its memories would appear to require reading trillions of synapses—many of them deep within the brain. Can that information be transcribed without destroying the brain in the process?

To add to the data-transfer challenge, our brains constantly change—strengthen, weaken, or completely rewire our synapses—as we see/hear/feel/touch/smell the external world, transfer data from short- to long-term memory, think, rethink in light of new information, dream, forget, and (like it or not) have our subconsciouses churn. In short: the brain is a complex, dynamic network. If the configurations of some synapses (say, in the outermost layers of the cerebral cortex) are read out earlier than others (say, within deeper layers), the transfer process may gather inconsistent information. Some transcription errors won't matter—we all carry around countless useless and half-forgotten memories—but other memories and thought structures are central to our sense of self.

Suppose we develop the technology to record a mind. To use that recording, we will also need the technology to transfer the information into a new container. That might be another biological brain—setting aside the ethical issues of overwriting whatever *was* or *might have been* in that recipient brain. (To an SF audience, one's hopefully healthier clone is an obvious receptacle. Clones—being copies, not improved versions—are beyond the scope of this article.)

Or, with suitable reformatting, a mind's contents might be written into a computer. For such an upload to be anything more than a static data dump, one will *also* need a brain simulation of sufficient fidelity to model the concurrent interactions among trillions of synapses. As it happens, the Human Brain Project has a billion-euro, European Commission-funded effort underway to develop just such a simulation (although it's aimed at basic research, not the uploading of minds). HBP's approach is to model the brain from the bottom up, starting with the simulation of individual neurons and progressing to larger and larger neuronal assemblages. The reductionist premise—that the brain is no more than the sum of its parts—has its share of neuroscientist skeptics. HBP has targeted 2023 for the simulation's completion.[22]

Are you, as am I, among those who believe in free will? Neuroscience has no explanation for this (unproven and unprovable) phenomenon. Computer programs *don't* have free will; they act either algorithmically or, when so programmed, with a good approximation to randomly. Mind, memory, self-awareness, and free will: there is much we would do well to better understand before attempting to upload a person into a computer.

None of which is to say uploads won't someday be possible, and in science fiction we're free to speculate. Suppose we can copy minds into a machine. What opportunities would such technology offer? What pitfalls might we encounter? Might one then make multiple mind copies? Modified copies? Herewith, a sampling of fictional explorations:

- Keith Laumer's 1968 novel *A Trace of Memory* has memory recording and rewriting for immortals whose natural rejuvenation process would otherwise cost them their memories.
- Daniel F. Galouye's 1964 novel *Simulacron-3* (the basis of the 1999 movie *The Thirteenth Floor)* and James P. Hogan's 1991 novel *Entoverse* have mind copies dropping in on the unsuspecting virtual residents of virtual worlds.
- *Annals of the Heechee,* 1987, the fourth novel in Frederik Pohl's Heechee saga, sees its protagonist uploaded after his physical death.
- Gregory Benford's 2000 novel *Eater* offers perhaps the most far-out copying scenario: minds coerced to upload into a passing sapient black hole that suffers from boredom.
- David Brin's 2002 novel *Kiln People* envisions mind copies uploaded into temporary servant bots, permitting people to be many places at once and (if/as desirable) to merge memories once a copy's task is complete.
- My 2011 short story "Blessed Are the Bleak" dystopically envisions uploading—a one-time "cure" for every ill that might befall a biological body—become the universal medical procedure.[23]
- Robert J. Sawyer's 2013 noir-on-Mars murder mystery *Red Planet Blues* envisions transferring a mind into a superior artificial body, and plenty of characters do just that. Their motivations include: exploring the Martian surface without breathing gear, mimicking the

(licensed) appearance of Hollywood idols, hiding out from their pasts, and potential immortality.

- Ramez Naam's 2013 novel *Crux* (the sequel to his aforementioned *Nexus)* includes a character, uploaded in desperation to save her life, going insane from sensory deprivation when denied a network link to a cloned biological body.[24]
- David L. Clement's 2015 story "Long Way Gone," sees a mind copy transmitted to a distant planet for installation into a recreated body (the informational content of DNA also being uploadable).[25]

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Better, smaller, faster

Not to mention cheaper and more parsimonious in its power requirements.

To what do I refer? Electronics, of course. Over recent decades computers have progressed from room-sized to pocket-sized, power-hogging to power-sipping, kilobytes in capacity to gigabytes, poky to blazingly fast. We give credit for this progress to *micro*electronics, but peel back the packaging of a modern integrated circuit and—if only you could see them—the feature sizes have shrunk to nanometers (billionths of a meter). As of 2015, state-of-the-art commercial chips have 14-nanometer features; chips in the lab are yet more finely detailed.

Once neural implants can connect a brain to a computer, it's hard *not* to expect that tiny general-purpose computers will sometimes reside inside the human body. Why? Many of us can't tear our attention away from our smart phones, even as we eat, socialize, or watch TV. Could we bear to have our future, yet more intimate internet connections go offline because some link drops?

Artificial intelligence (AI) is a topic for an entire article, but let's suppose that AI becomes widespread. Let's suppose that internet-accessible AIs come to provide us with ever more expert advice, subtle data mining, natural-language translation, and other information-intensive services. Surely many people equipped with neural implants would then use that interface to interact routinely with such AIs.

But why limit ourselves to network-accessed AI? Our favorite genre doesn't:

- Greg Bear's 1983 novelette "Blood Music"[26] (and its 1985 novelized version) offered AI based on modified human cells injected into a human host.
- More recently in *Analog,* the feminine side of Richard A. Lovett's "Floyd and Brittney" series is a chips-resident implanted AI.
- In my 2009 novel *Small Miracles,* the invading smart nanites are nanomechanical and their signaling biochemical.
- The "Augmented" characters of my 2015 novel *InterstellarNet: Enigma* are hybrids: human and AI minds fully integrated within one skull.
- *Star Trek: The Next Generation* gave us that sinister multi-species AI/cyborg collective, the Borg.

* * *

Oh, behave!

Every computer- and data-centric application raises issues of security and privacy—even as almost every day brings a fresh reminder of just how inadequate are our cyber defenses.[27] When we put our personal genome, real-time medical condition, and artificial organs online, the challenges only become more critical. And when even our brains (or uploaded minds) become available online?

Scary!

In "Broken Hearts," an episode of the 2011 TV series *Homeland,* terrorists kill the vice president by remotely accessing his cardiac pacemaker. The real-life Department of Homeland Security has concerns about hacking of medical devices, launching a study of prospective vulnerabilities within two dozen separate devices.[28]

Before humanity can reach our full version 2.0 potential, cyber security must undergo its own revolution.

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To wrap up

Genetically reengineered people. Artificial organs. Cyborgs and full-body prostheses. Uploaded minds and AI/human syntheses. Many or all of the above at once. In the years to come, more likely than not, we Mark I, purely evolved humans will find ourselves among *very* interesting company.

When the Human 2.0 era arrives, will old-fashioned humans be able to compete? Will everyone undergo the change(s) or will some of us take refuge in—or find ourselves exiled to—(human-)nature preserves? Will we impose these change(s) upon our children? Will sinister forces exploit security vulnerabilities in our altered forms to coerce, control, or kill us? Will there be modifications beyond those we've already considered, transformations that we mere Human 1.0 types are unequipped even to imagine?

There's much opportunity in these uncertainties for storytelling. More importantly, I suspect, we'll need all the fictional scouting of this onrushing future that the genre can offer.

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Acknowledgment

Henry G. Stratmann, M.D. (and a frequent Analog *contributor), reviewed a draft of this article. I appreciate his thorough and thoughtful comments.*

To read further:

- *The Future We Deserve: IEEE Spectrum 50th Anniversary Issue,* June, 2014.
- *Hacking the Human OS: IEEE Spectrum Special Report,* June 2015.
- *More Than Human: Embracing the Promise of Biological Enhancement,* Ramez Naam.
- *Beyond Human: Living with Robots and Cyborgs,* Elisabeth Malartre and Gregory Benford.
- *Using Medicine in Science Fiction: The SF Writer's Guide to Human Biology,* Henry G. Stratmann, M.D.
- *Science Fact and Science Fiction: An Encyclopedia,* Brian Stableford (editor), articles: cyborg, eugenics, genetic engineering, neurology, posthuman.
- Humanity+ *(http://humanityplus.org/)*

Footnotes:

[1] In the January/February 2015 *Analog.*

[2] "A sight for blind eyes," Margaret Harris, *Physicsworld.com,* February 13, 2015, *http://blog.physicsworld.com/2015/02/13/a-sight-for-blind-eyes/.*

[3] "Could bionic eye end blindness?" Dr. Sanjay Gupta and Kristi Petersen, *CNN,* June 13, 2002, *http://edition.cnn.com/2002/HEALTH/06/13/cov.bionic.eye/.*

[4] I am reminded of the (film!) camera within a spy's false eye in the 1969 movie *Journey to the Far Side of the Sun.*

[5] "The End of Disability . . ." Op. cit. Part I, *Analog* January/February 2016.

[6] "FDA Approves New Appetite Pacemaker Device," Maggie Fox, *NBC News,* January 14, 2015, *http://www.nbcnews.com/health/diet-fitness/fda-approves-new-appetite-pacemaker-device-n286166.*

[7] "The Vagus Nerve: A Back Door for Brain Hacking," Samuel K. Moore, *IEEE Spectrum,* May 29, 2015, *http://spectrum.ieee.org/biomedical/devices/the-vagus-nerve-a-back-door-for-brain-hacking.*

[8] Both these short stories appeared in the July/August 2015 *Analog.*

[9] "Scientists switch 'good' and 'bad' memories in mice," Rachel Feltman, *Washington Post,* August 27, 2014, *http://www.washingtonpost.com/news/speaking-of-science/wp/2014/08/27/scientists-switch-good-and-bad-memories-in-mice/.*

[10] "MIT scientists implant a false memory into a mouse's brain," Meeri Kim, *Washington Post,* July 25, 2013, *http://www.washingtonpost.com/national/health-science/inception-mit-scientists-implant-a-false-memory-into-a-mouses-brain/2013/07/25/47bdee7a-f49a-11e2-a2f1-a7acf9bd5d3a_story.html.*

[11] "DARPA Project Starts Building Human Memory Prosthetics: The first memory-enhancing devices could be implanted within four years," Eliza Strickland, *IEEE Spectrum,* August 27, 2014, *http://spectrum.ieee.org/biomedical/bionics/darpa-project-starts-building-human-memory-prosthetics/.*

[12] “Scientists Connect Two Human Brains At Different Locations,” James Kosur, *Business 2 Community,* November 7, 2014, *http://www.business2community.com/tech-gadgets/scientists-connect-two-brains-different-locations-01062010.*

[13] Neurogaming responds to the game player’s physiological state. Possible inputs include heart rate, pupil dilation, and—with an EEG-type headset—brainwaves. Past video gaming helped advance the state of the art in computer graphics; perhaps gaming will also foster the development of BMIs.

See “Neurogaming: Interest growing in technology that picks players’ brains,” Steve Johnson, *San Jose Mercury News,* June 13, 2014, *http://www.mercurynews.com/business/ci_25957073/neurogaming-interest-growing-technology-that-picks-players-brains.*

[14] In the May 1962 *Analog.*

[15] Serialized in the October and November 2002 issues of *Analog.* In expanded form, this story and “Presence of Mind” (the novella in the February 2002 *Analog)* comprise much of my 2008 novel *Fools’ Experiments.*

[16] See my blog post *http://blog.edwardmlerner.com/2014/06/the-neural-interface-you-always-wanted.html.*

[17] See “Carbon nanotube fibers make superior links to brain,” March 25, 2015, *Phys.org, http://www.phys.org/news/2015-03-carbon-nanotube-fibers-superior-links.html.*

[18] Fueling one’s BMI may be one more reason to eat chocolate. For more conventional pluses, see “What are the health benefits of chocolate?” Joseph Nordqvist, MNT, June 22, 2015, *http://www.medicalnewstoday.com/articles/270272.php.*

[19] Or how about a nefarious party reclaiming the central nervous systems of the recently deceased as building blocks for cyborgs, à là 1987’s movie *Robocop?* Echoes of Dr. Varsag and his mongoose . . .

[20] See “Russian Mogul’s Plan: Plant Our Brains in Robots, Keep Them Alive Forever,” Katie Drummond, *Wired,* February 29, 2012, *http://www.wired.com/2012/02/dmitry-itskov/* and “Scientists Are Convinced Mind Transfer Is the Key to Immortality,” Meghan Neal, *Motherboard,* September 26, 2013, *http://motherboard.vice.com/blog/scientists-are-convinced-mind-transfer-is-the-key-to-immortality.*

[21] A part of each neuron is a branching structure of projections, axon and dendrites, through which one neuron electrochemically signals to other neurons (and, outside the brain, to other cell types). A synapse is a particular junction between cells.

[22] “Will we ever . . . simulate the human brain?” Ed Yong, *BBC News,* February 8, 2013, *http://www.bbc.com/future/story/20130207-will-we-ever-simulate-the-brain.*

[23] In the April 2011 *Analog.*

[24] Nor is sensory deprivation the worst abuse to which an uploaded mind might be subjected. In “An Immense Darkness” (March 2015 *Analog),* Eric James Stone finds ways to torture and interrogate the involuntarily uploaded mind copy of a terrorist. It’s critical we determine *before* we have upload tech: what are a mind copy’s legal rights?

[25] In the January/February 2015 *Analog.*

[26] In the June 1983 *Analog.*

[27] Breaking cyber-(in)security stories as I type (June, 2015): “Hack affected every single federal employee, union says,” Laura Hautala, *CNet,* June 11, 2015, *http://www.cnet.com/news/hack-affected-every-single-federal-employee-union-says/* and “Latest hack on federal employees targets security clearances,” Laura Hautala, *CNet,* June 12, 2015, *http://www.cnet.com/news/new-hack-on-federal-employees-targeted-security-clearance-information/.*

[28] “U.S. government probes medical devices for possible cyber flaws,” Jim Finkle, *Reuters,* October 22, 2014, *http://www.reuters.com/article/2014/10/22/us-cybersecurity-medicaldevices-insight-idUSKCN0IB0DQ20141022*

About the author

A physicist and computer scientist, Edward M. Lerner toiled for thirty years in the vineyards of aerospace and high tech. Then, suitably intoxicated, he began writing science fiction full time. When not prospecting beneath his sofa cushions for small change for his first spaceflight, he writes technothrillers like *Energized* (powersats), the InterstellarNet adventures of First *and* Second Contact, and, with Larry Niven, the Fleet of Worlds series of space operas.

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