Chapter 9

INVENTION FOR THE PEOPLE

Through much of the twentieth century, the word "technology" conjured up the dirty, rusty, smelly, often invisible infrastructures of the first industrial revolution: "on tap but not on top," as Winston Churchill reportedly said of scientists advising governments. By the turn of the century, however, technology had come to be seen as a dynamic force for social change, bearer of ever larger hopes and fears as a global populace grew aware that technologies can transform, dramatically and perhaps irrevocably, the purposes and conditions of human existence. For the world population as a whole, the technological breakthroughs of the late twentieth century promised better health, swifter communication, cleaner environments, and unimaginable riches in knowledge and information. On the level of the individual human subject, the same technologies—powered by advances in nano-, bio-, info-, and cogno-sciences—created expansive opportunities for refashioning the self, offering hitherto unimaginable enhancements of life, along with fears that such powers might be misused or overused to humankind's lasting detriment.

The threat of nuclear annihilation was one powerful driver of a new global focus on technological risks, but from the 1980s onward technologies signaling what insiders called

"convergent disruption" amplified public expectations about enhanced human capabilities while arousing new anxieties about technology's controlling and pervasive influence. Biotechnology promised miracles of life and health but awakened deep-seated concerns about environmental degradation and moral decay. More recently, developments in nanotechnology, synthetic biology, cognitive and neurosciences, and, above all, computing capability have focused attention on technology's immense potential to redefine the meaning of being human. Information technologies, in particular, herald an era in which the proliferating uses of personal data will render human subjects vulnerable to being mined and monitored as never before, and big data and algorithms may displace human discretion as apparently infallible instruments of governance. Meanwhile, climate change, a fearsome legacy of an older era of industrial production, hangs over the planet as a specter of what can happen when our appetite for technological advances is not reined in. Even in confronting this extreme threat, however, some remain confident that technology provides the best antidote for its own poisons, whether in the form of geoengineering to cool the Earth, new energy technologies to enable growth without pollution, or the ultimate science fiction fantasy of escaping to planets not wrecked by human mismanagement.

A trio of commonly held but flawed beliefs, each suggesting that technologies are fundamentally unmanageable, and therefore beyond ethical analysis and political supervision, long impeded systematic thinking about the governance of technology. The first is technological determinism, which holds, contrary to centuries of historical experience, that technologies have a built-in momentum that shapes and drives the course of history. The second is technocracy, which implies that only

skilled and knowledgeable experts possess the competence to govern the advance of technology. The third is unintended consequences, a notion that implicitly positions the harms caused by technology outside the ambit of intention or forethought, and thus breeds fatalism about the very possibility of bringing our nonhuman, mechanical, or cognitive collaborators under meaningful human control.

We have seen throughout this book that technological systems are in fact more plastic and more amenable to ethical and political oversight than these strands of conventional wisdom hold. The making and deploying of technologies have given rise to ethical questions on multiple levels, from how to protect individual values and beliefs to how much respect to accord to the policy intuitions of nation-states informed by distinctive legal and political cultures. These questions gained urgency through the global spread of technology in the later twentieth century, and they impose on technologically advanced societies an obligation of active public reflection and response. Pharmaceutical drugs, for example, were once seen simply as miraculous breakthroughs in medical knowledge and practice, bringing benefits to all humanity. In the global marketplace, however, drugs have become entangled with a host of normative issues bearing not just on national but on transnational rights and duties. These include ownership of human biological materials, privacy of medical data, consent to clinical trials, ethics of human subjects research, manufacture of generic drugs, access to experimental and essential medicines, protection of indigenous knowledge, and many related matters. On all of these issues, stakes and expectations vary widely, depending on the observer's socioeconomic position—sick or well, rich or poor, producer or consumer, and citizen of a developed or a developing country. Pharmaceuticals thus exert power far beyond their immediate properties as

therapeutic agents: they reconfigure the human body in transnational space, as an object of science, medicine, economics, law, and policy. Yet processes of deliberation on the politics and ethics of drug development remain significantly less available at the supranational than at the national level.

How can our far-reaching technological inventions be governed so that they meet the ethical needs of a globalizing world? Who should assess the risks and benefits of innovation, especially when the results cut across national boundaries: according to whose criteria, in consultation with which affected groups, subject to what procedural safeguards, and with what remedies if decisions prove misguided or injurious? Technological mishaps and missteps continually alert us to the need for deeper social, political, and legal analysis. Yet many basic issues of right and wrong remain deeply contested, and principles for resolving them glimmer at best weakly on the horizon. This concluding chapter reviews the major insights gleaned from decades of national and global experience with the governance of technological systems, as discussed and exemplified in earlier chapters. The challenges that still lie ahead are grouped under three thematic headings that tie those histories together: anticipation, ownership, and responsibility.

ANTICIPATION: AN UNEQUAL GIFT

If there is one thread that runs through all policy discourses on technology, it is the need for wise anticipation. The technology assessment programs of the 1970s and 1980s grew out of an interest in foreseeing and forestalling technologically induced physical and environmental harms. Similarly, programs to evaluate the ethical implications of new technologies reflect a widely

distributed desire to anticipate and ward off insupportable moral harm. Unsurprisingly perhaps, in modern societies anticipation of both physical and moral consequences is closely tied to expert predictions of likely outcomes. The linear model of technology policy, which begins with risk assessment and only later injects values into decisionmaking, delegates the initial phase of anticipation to experts, or technocrats, who are thought to understand best how technology operates, and where it may go wrong. Yet, as the stories scattered through the preceding chapters illustrate, experts' imaginations are often circumscribed by the very nature of their expertise. The known takes precedence over the unknown. Accordingly, anticipation by experts tends to foreground short-term, calculable, and uncontested effects over those deemed speculative, far-fetched, or politically contentious. And, drunk with the mastery of pathbreaking scientific insights, experts too often underestimate the complexities of hybrid sociotechnical systems, in which ill-understood dynamics and feedbacks between human and nonhuman elements confound the precision of lab-based expectations.

Who Imagines the Future?

In the early, promissory stages of technological change, foresight is often shaped and limited by the disciplinary competence of expert advocates. The molecular biologists at Asilomar were determined to prevent a biological catastrophe, but they did not imagine a world reshaped by commercial biotechnology in which major GM crops would routinely displace their wild counterparts, even though that world came into being in America within decades of the discovery of recombinant DNA technology. The German engineering companies that conceived the transfer of solar energy from the Sahara to

Europe did not think about the political management of such an audacious transnational project, spanning vastly different cultures and economies, and Desertec eventually fell victim to the ungovernability of its designers' imagination.

Institutional conservatism also precludes farsighted prediction. Courts, for example, seek to ensure stability in the law, but at the cost of ignoring the values affected by technological transformations. Genentech's characterization of Ananda Chakrabarty's bacterium as mere matter won out in a common-law high court that preferred the biotech company's incremental vision over Jeremy Rifkin's seemingly unfounded concerns about a slippery slope from the patenting of bacteria to the patenting of higher animals. In hindsight, however, it seems that Rifkin more accurately foresaw the likely trajectory of patenting life than Genentech and its prominent advocates in the scientific community. The Canadian Supreme Court's rejection of a patent on the oncomouse and the U.S. Supreme Court's own retreat from patenting human genes display a retroactive (some might say belated) repudiation of the more extreme implications of patenting life.

In expert thinking, too, there is frequently a tacit slippage between is and ought that dulls the edge of ethical concern. Any departure from the common sense of scientists is deemed unreasonable, fictional, or fantastic, and what cannot (yet) be done is not considered worth worrying about. Invention, as we have seen, tends to be regarded as a good in itself, with ethical oversight invoked chiefly to ensure that the promised good will not be derailed through a reckless greed for profit. Predictions of technical improbability then serve as a barrier against potentially "unrealistic" ethical speculation and premature public anxiety. Consider, for example, a brief entry from *Science*'s 2013 list of runners-up for breakthrough of the

year. Under the heading "Human Cloning at Last," the journal reported, "This year, researchers announced they had cloned human embryos and used them as a source of embryonic stem (ES) cells—a long cherished goal." The report went on to downplay the ethical meaning of this development, citing improbability rather than moral aversion as the reason why society should not worry: "The feat also raises concerns about cloned babies. *But that seems unlikely for now.* Despite hundreds of tries, the Oregon researchers say, none of their cloned monkey embryos have established a pregnancy in surrogate females" (emphasis added).[1] Silenced in this account is the what-if question. Suppose a pregnancy had been established and cloned babies made to seem more probable. Is it fitting that societies of such infinitely creative capacity as ours should reflect on the ethical implications of such far-reaching technological experiments only after a threat to human dignity comes knocking at the door?

In the world of innovation imagined by the *Science* report, one wonders when, if ever, it would be appropriate for the public to voice concerns about cloned babies. Only after researchers in Oregon or elsewhere announced they had succeeded in inducing a pregnancy with their cloned embryos? Surely, though, by that stage a new "is" would overwhelm the possibility of a more nuanced and precautionary "ought"—such as a rule that might have made researchers think twice, or think aloud in public, before making the "hundreds of tries" to induce an ethically controversial pregnancy. Further, the description of human embryo cloning as "a long cherished goal" overlooks the contested and divergent moral settlements that exist across nations about where an embryo ends and a baby begins. In Germany, for example, concern might arise further upstream in the research process than in the United States, illustrating different preferences for

deontological as opposed to utilitarian arguments in two nations whose ethical thinking is, in both cases, rooted in the "Western" tradition. Given such disparities in basic commitments to ethical reasoning, is it even appropriate for decisions of such consequence for the entire human species to be undertaken by technologically leading nations going it alone?

With confident expert assertions as a baseline for moral analysis, ethical assessments tend in any case to devolve into utilitarian analyses of the costs and benefits of probable scenarios. This is exactly what happened when two different U.S. presidential ethics commissions evaluated human cloning and synthetic biology, respectively. In each case, the commission concluded that there were no ethical worries at present because the technology was not yet sufficiently safe to use.[2] Principled questions about which kinds of worlds, containing what forms of life, should be made with technology got sidelined in favor of shallower assessments of imminent risk. Such disappointingly constrained exercises contradict the hopes of some democracy theorists that anticipatory governance, enacted through procedures such as constructive technology assessment (see chapter 8), "can contribute to bending the long arc of technoscience more toward humane ends."[3]

Trickle-Down Innovation

Modern societies have committed extensive resources of money and expertise to anticipating adverse technological futures and warding off potential ill effects, but those resources are unevenly distributed across nations and technological domains. Events like the 2013 Rana Plaza factory collapse in Bangladesh speak to a global political economy in which the lives of the poor are placed at risk in ways that would be deemed intol-

erable in richer countries. Astonishingly, responsibility proved almost as hard to pin down in 2013, after the textile industry's worst-ever disaster, as it had been nearly thirty years earlier, in 1984, when the Union Carbide plant in Bhopal released a deadly cloud of methyl isocyanate over a sleeping, unsuspecting city. It took more than two years for charges against Sohel Rana to be formalized. Although many clothing companies employing Bangladeshi labor pledged contributions to a compensation fund, there was no global forum in which lines of responsibility could be formally established or major transnational actors be publicly held to account. To the extent that risk assessment is meant to foresee and prevent such horrific accidents, it has not yet caught up with the challenges of prediction and protection under conditions of severe global economic, political, and informational inequality.

The failures of risk assessment can also be attributed to the narrow causal frames that have historically underpinned this widely used anticipatory technique. Construed as a "science," risk assessment perennially downplays social factors and overemphasizes variables that can be quantified as against more elusive economic, institutional, and cultural contributions to risk creation. It took two space shuttle disasters, the loss of the *Columbia* as well as the *Challenger*, for U.S. accident experts to begin identifying organizational conditions within NASA that made these tragedies possible. The cataclysmic Bhopal disaster produced no comparable moment of reckoning. It led to what many still see as a premature and unjust settlement, precluding a fair adjudication of all that went wrong when a highly hazardous technology was transferred between nations lacking parity in wealth and expertise.

Despite its limitations as an instrument of governance, anticipation is a value no society would care to live without. Throughout

history, human beings have turned to anticipated futures—whether in this life or one after—as a means of offsetting the terrors and trials of the present. Visions of a better world have driven inventors to imagine and create new tools, from the steam engine, cotton gin, and lightbulb to today's genetically modified Innate potato, which is alleged to produce less cancer-causing acrylamide when fried.[4] Visions of emancipation fire the California-based Singularity University's ambition to improve lives on an exponential scale, one billion people at a time.[5] Anticipation in this optimistic sense also powers the economics of innovation. Investors buy shares in fledgling technology companies in anticipation of elevated profits somewhere down the long road of research and development. Consumers, too, do their part, as when they hang on Apple's latest moves, anticipating unimagined gains in sleekness, versatility, and speed. One of the blessings of modernity is that the gap between idea and actualization has been shortened. Our ability to translate knowledge into inventions has grown along with our scientific and economic resources. There has never been a time in human history when bright ideas were more likely to attract quick attention, venture capital, and the legal and political support needed to bring them into global markets, in usable form and in real time.

As yet, though, the luxury of positive anticipation is limited largely to those who already have much, and hence are well positioned to dream up what it would mean to have still more. Steve Jobs's famous claim that he knew what consumers want before they themselves did was formulated in an economy of plenty, not want; Jobs presumed that people would not only want but also have the resources to buy the beautiful gadgets he dreamed up for them. But most of the world's masses are in no position to anticipate for themselves either immediate ben-

efits or improved long-term prospects from the forward march of technology. They must accept the promise of benevolent outsiders that their lives will be bettered through inventions designed elsewhere, by entrepreneurs closer to technology's moving frontiers, with the capital and know-how to engineer large-scale change. Inequality—not only of access but even more of anticipation—thus emerges as an unresolved ethical and political barrier to the just governance of technological innovation.

One idea that has gained ground to offset the unfair imaginative advantages enjoyed by technologically and economically better endowed societies is "frugal innovation" or "frugal engineering." Frugality here means making technologies that are better adapted to the means of the less well-off. A poster child is the $100 laptop project initiated by Nicolas Negroponte of the Massachusetts Institute of Technology and embraced by former UN Secretary-General Kofi Annan in 2005. The goal was to create an easily affordable computer for worldwide distribution by stripping away unnecessary frills and equipping it to work under unfavorable conditions such as the erratic power supply that plagues most developing nations. Frugal innovations embrace everything from the Indian Tata Group's Nano, the cheapest car in the world, to the Nokia 1100, a popular, stripped-down cell phone, and Unilever's single-use toiletries. One could even see the rise of the "shared economy"—with its transformation of "extra" rooms, cars, and even pets into spare capital—as a kind of frugal innovation potentially using the spare goods of the haves to benefit the masses of have-nots.

Although they gained ground in the economics of plenty (where else is there so much stuff to spare?), shared economies arguably bear a family resemblance to Muhammad Yunus's influential notion of microcredit, which also drew on the princi-

ple that one need not have much to be able to share and thereby produce more profit for all. Additionally, certain material innovations for the poor, such as smokeless cooking stoves, composting toilets, and simple water purification systems, have drawn the attention of Northern engineers and scientists and could prove hugely beneficial. On the whole, however, the gap between the subsistence innovations aimed at the poor and the kinds of visionary ideas that propel breakthrough developments in the convergent technologies of wealthy societies remains as staggering as ever.

Laudable as the "no frills" commodities are, they still largely represent a kind of trickle-down theory of innovation, in which the technological achievements of the wealthy and well resourced define the anticipatory horizons of the less privileged. What the rich invented to fit their circumstances remains the gold standard for what the poor should need and want, only with fewer features, less sensory appeal, and possibly less likelihood of serving as platforms for autonomous development.[6] The problem of innovation is rarely posed in reverse. What kinds of technological futures would make most sense for the two-fifths or so of the world's population who subsist on less than two dollars a day?[7] Should they spend fifty days of scarce income on a kid's laptop, or are there more pressing demands that technology could more advantageously correct? In any case, would having the laptop open doors to the sorts of playful yet productive connections (Facebook, Reddit, Pinterest, Instagram) that the rich can effortlessly imagine and indulge in?

The power differential that permeates the design of technological futures is worrisome, but that is not humanity's only ethical concern. Indeed, in an era when we are more than ever conscious of the unsustainability of high-consuming lifestyles, it is unclear that the futures envisioned by the rich should take

precedence over the imaginations of the poor. As downsizing, greening, simplifying, and even "freeganism" (living from others' unwanted trash) rise in appeal among the young, better ideas for how to live more lightly on Earth may well need to come from below, ideas that pay more attention to the values of social cohesion and stewardship than to the ceaseless imperialist exploitation of living and nonliving materials.

OWNERSHIP AND INVENTION

Technological development over the past several centuries owes as much to ideas of property, or private gain, as to anticipations of the collective good. New technologies as often as not involve new modes of extraction, generating huge profits for those who discover how to access and distribute previously unappropriated resources. Prospecting and mining are obvious examples, but technology has enabled many other forms of resource use, often linked to projects of state and imperial expansion. California became a modern state in the mid-nineteenth century through an influx of hundreds of thousands of immigrants staking claims to newfound gold. Diamond mines supported Cecil Rhodes's imperial ambitions in South Africa, and the rubber and ivory trade underpinned King Leopold II's brutal regime in the Congo. Exploitation, cruelty, and misuse of power overshadowed these enterprises, but so long as demand existed for the commodities they generated, technology, economics, and politics combined to keep oppressive regimes in place.

Whereas the earliest extractive technologies pulled things that people already valued out of rocks, earth, plants, and oceans, many technologies of today assign value to things that were not historically treated as commodities. Biological mate-

rials, everything from genes to novel lab-created entities, such as the cancer-prone Harvard oncomouse, belong in this category. Constructs such as carbon markets and ecosystem services have turned parts of nature into tradable commodities, although one cannot own or use them in the way one uses gold. Also in this category are the burgeoning compilations of big data produced through the information revolution.[8] Social media have commodified people's habits and preferences, their memories and their aspirations, through large-scale aggregation. Facebook trades on the fact that more than a billion people wish to be connected to their "friends" and are willing to contribute masses of personal information to a private enterprise in return for reaching those friends and knowing what they are up to. Twitter capitalizes on people's passing thoughts in 140 characters and attached images that few would have seen fit to share until the Internet enabled fleeting impressions, mental or visual, to be disseminated to global audiences. Pinterest thrives on people sharing dreams of weddings, vacations, home renovations, and other things people want to welcome into their anticipated futures. Direct-to-consumer testing companies compile databases of voluntarily supplied genetic information that have commercial potential for pharmaceutical research and development. All of these technological systems profit from people in novel ways, mining their thoughts, words, habits, bodies, and emotions as resources to create new marketable goods.

The tortuous story of the HeLa cell line demonstrated that people's sense of control over their own bodies—and perhaps even more their minds—can diverge significantly from the presumptions of ownership built into existing law and policy. Rebecca Skloot's prizewinning reconstruction of Henrietta Lacks's story ignited a volatile mix of one of modern biology's most useful research tools and America's perennially vexed narratives of

race and poverty. The National Institutes of Health recognized a public relations disaster in the making if the moral claims of a historically excluded group, intimately bound up with past failures of biomedical ethics, were left untended. A onetime procedure solved the NIH's immediate problem, granting the Lacks family the right to participate in decisions involving their ancestor's biological legacy. Shorn of its unique historical and political trappings, the case of the HeLa cell line would likely have foundered, leaving Henrietta Lacks to die a second death. That extraordinary example is unlikely to serve as a persuasive precedent for situations in which science and its objects of study enjoy less symmetrical bargaining positions.

For the most part, the intellectual property regimes that govern technological innovation continue to uphold ideas of ownership and capital that originated in the modern industrial world some two hundred years ago. These ideas are not completely homogeneous, of course, even across Western nations. European patent law differs from its American equivalent in providing an explicit mandate against inventions that violate *ordre public*, or morality. European law also sets higher bars for demonstrating what constitutes an "inventive step" than U.S. law in its most permissive phases, as when the Patent and Trademark Office for a time granted patents on isolated DNA fragments of no demonstrated utility. On the whole, however, intellectual property hides its normative foundations—such as favoring individual entrepreneurship over collective effort—beneath a veil of technical neutrality. In the Gleevec case (see chapter 7), the Indian Supreme Court explicitly stated that patent law is an instrument of economic development, so that the scope and nature of the protections it offers should reflect "the economic conditions of the country."[9] Such language underscoring the normative foundations and power asymmetries of

intellectual property rights is rarely encountered in Western legal decisions.

Yet the law can also confirm or destabilize ownership claims whose entanglement with public concerns about autonomy, privacy, life, or health have become visible and undeniable. Legal power emerged as salient in the U.S. Supreme Court's 2013 decision to discontinue the patenting of human genes, overriding the Patent and Trademark Office's policy that had held otherwise for decades. Years of activism by a public interest group, the American Civil Liberties Union, undid a commodifying move that violated tacit but widely held public values about the rightfulness of privatizing parts of the human genome. Such about-faces can occur even in the international arena, although here the driver tends to be political economy rather than the politics of personhood. Thus, the Convention on Biological Diversity sought to reverse centuries of unregulated biopiracy by recognizing the ownership claims of indigenous knowledge holders. The treaty provides for profit sharing between local communities and bioprospecting companies that develop new therapeutic compounds by using local knowledge and materials. Economic disparities in the distribution rather than the production of drugs motivated the 2001 Doha Declaration, amending the Agreement on Trade-Related Aspects of Intellectual Property Rights (the TRIPS Agreement). TRIPS now allows countries to circumvent pharmaceutical patent rights in emergency situations such as the AIDS crisis that require rapid, expanded access to essential medicines. Unexamined questions for the future include how to recognize distributed ownership of intellectual property as invention, increasingly, relies on the circulation and synergy of people, ideas, and materials across formerly unbridgeable geopolitical boundaries.

RESPONSIBILITY: PUBLIC AND PRIVATE

Technological advances can remake the divisions between public and private spaces in ways that affect not only personal autonomy and opportunities for public deliberation but also, and perhaps more significantly, the norms of individual and collective responsibility. From Karl Marx to Herbert Marcuse, social theorists have warned of the flattening, standardizing, and dulling effects of technology on the human spirit, through the spread of industrial work practices and mass culture. Inside the iron cages of large technological systems, subject to the tyranny of the assembly line and the production quota, emancipation and responsibility for the self may sound like cosmic jokes. New biological and informational technologies carry big promises of liberation, especially from inherited disease; but they also allow unprecedented access into bodies and minds and create possibilities for social control that surpass even the Orwellian nightmare of *Nineteen Eighty-Four.*

To some degree, people themselves have proved complicit in shrinking the boundaries of the private in the digital age. The rise of the culture of the selfie (self-portraits taken with handheld cameras) and people's seemingly limitless appetite for attracting the gaze of others have created an intoxicating space in which indiscretion can wreck employment prospects, ruin political careers, and intrude into zones that even celebrities once kept to themselves.[10] As murky as they are pervasive, data sets have emerged as a prime source of contestation in the struggle between individual self-control and overweening state and corporate power. Data oligarchs currently operate under a patchwork of state-sponsored and self-imposed regulation, such as Google's and Facebook's privacy policies, reflecting disparate

normative commitments. To bring information's wild frontiers under anything approaching systematic control may require wider adoption of concepts such as the European Union's "data subject," as well as sustained debate on what people know, expect, and will tolerate with regard to the circulation of data about their preferences and their persons.

A different kind of ethical worry stems from the retrenchment of the very idea of "public-ness" in an era dominated by market thinking and neoliberal forms of governance. Legislatures, classic seats of representative democracy, seem increasingly less relevant in a time when big money can exert pressure on public opinion through a wide diversity of channels. Entrepreneurs fiercely resist legislation, arguing (particularly in the United States) that it stifles innovation because law constantly lags behind science and technology. Charismatic figures such as Sir Timothy Berners-Lee, inventor of the World Wide Web, and Craig Venter, co-sequencer of the human genome, point to the success of the Internet and the spread of biotechnology as prime examples of the benefits of laissez-faire technological development. Legislatures for their part often lack courage and expertise to fight back, and may be politically beholden to the very interests that they are theoretically committed to keeping under control.

The explosion of ethics bodies dedicated to specific technological developments—biomedicine, nanotechnology, synthetic biology, neurosciences—should offer relief against private capture of public policymaking institutions, but in practice these often invisible committees add to the layers of ethical concern. When tied too closely to the research enterprise, bodies such as institutional review boards supervising human subjects research tend to operate with a tacit commitment not to burden their home institutions or their scientific stars with too many

demands. As we have seen, even the more visible national ethics commissions prefer the safe haven of cost-benefit analysis of imminent technological futures to asking hard questions about the longer-term public benefits of new lines of research. Britain's Warnock Commission, for example, performed a huge service for modern biomedicine by characterizing the pre-fourteen-day embryo as a nonhuman for research purposes. In Britain, that bright line created a permissive space for frontiers research using embryonic tissues and led to several first-time approvals for new ethical extensions, as in the use of "savior siblings" to provide matching tissue for an ill child or the making of the three-person embryo to eliminate the mother's mitochondrial genetic disease. Yet, left unchecked, this relative privatization of public morality inside closed-loop ethics bodies may spawn public alienation and normative rejection. Ongoing U.S. controversies over issues such as stem cell research reveal the political vulnerability of prescriptive line-drawing by ethical experts whose views are not exposed to ongoing public scrutiny and reapproval.

CONCLUSION

Modern societies, in the past hundred years, have invented many strange and wonderful things and broken unimagined barriers in mobility, communication, calculation, and preservation of life and health. With technology, we have turned famine to surplus, eliminated killer diseases, plumbed the oceans and the stratosphere, brought outer space within the horizons of human imagination, and opened up the recesses of the human mind to targeted exploration. Much of the world rejoices when [illegible] on Mars or on a comet, in a feat of accuracy that

some say is like throwing a hammer from London and hitting a nail in New Delhi. The dream of constructing reusable rockets became a reality in December 2015 when a company headed by the U.S. technology entrepreneur Elon Musk successfully landed a rocket back on Earth after launching satellites into orbit. Concurrently, huge strides have been made in monitoring, modeling, and measuring the impact of technological activities on health, environment, and society. Technological cultures are no longer so heedless of nature as when nineteenth-century factories belched smoke and acrid dust over pristine landscapes, toxic dyestuffs ran into rivers uncontrolled, or companies hid evidence that workers exposed to asbestos were dying of lung disease in the thousands.

Yet, as we have seen throughout the preceding chapters, institutional deficiencies, unequal resources, and complacent storytelling continue to hamper profound reflection on the intersections and mutual influences of technology and human values. Important perspectives that might favor caution or precaution tend to be shunted aside in what feels at times like a heedless rush toward the new. As a result, the potential that technology holds for emancipation, creativity, and empowerment remains unfulfilled or at best woefully ill distributed. Issues that cry out for careful forethought and sustained global attention, such as the genomic and information revolutions, are depoliticized or rendered invisible by opportunistic design choices whose partially path-dependent tracks frustrate future creativity and liberation.

The life history of the automobile, one of the twentieth century's most successful technological inventions, and still a fetish of wealth the world over, remains a paradigmatic case study in the limits of human foresight. The car unlocked immense possibilities for individual freedom and productivity, but these

went hand in hand with drastic consequences for society that no one had imagined or regulated in timely fashion: more than a million traffic deaths worldwide each year, the spread of deadening, routinized work practices, the blight of urban air pollution, the fragmentation of communities, the decay of once-great manufacturing centers, and eventually world-threatening climate change. Could current practices of responsible innovation and anticipatory governance have turned the tide of the automobile's history before it took a tragic course? For technologies of mass appeal and enormous economic and social consequence, the localized and episodic processes of governance commanded by nation-states seem sadly inadequate. Occasional mobilization, moreover, fails to get to the heart of the asymmetries of anticipation. For all practical purposes, the power to set the rules of the game for governing technology rests with capital and industry, not with the political representatives of the working, consuming, and too often suffering masses.

This deep democratic deficit cannot be cured with procedural Band-Aids. The recently proliferating experiments with public consultation, constructive technology assessment, and ethical review do no harm and should certainly continue. They have the merit of keeping people involved in decisions pertaining to their everyday lives, and over time they may clarify a society's preferences for rule by technology. Such ad hoc processes, however, are not a substitute for the kind of constitutional convention that our grand bargain with technology in effect demands. To unleash the potential of the democratic imagination, contemporary societies will have to acknowledge first of all that technology is neither self-propelling nor value-free. Even modest technological improvements create new normative rights and obligations, as when I have to cross the street in Cambridge under the watchful eye of traffic lights at an intersection that

once was unregulated. The parallels between technology and law then become apparent, showing that the former no less than the latter is a potent instrument for fashioning our collective futures. That recognition should spur a deeper ethical and political engagement in the governance of technology. Only if we acknowledge technology's power to shape our hearts and minds, and our collective beliefs and behaviors, will the discourses of governance shift from fatalistic determinism to the emancipation of self-determination. Only then will an ethic of equal rights of anticipation be accepted as foundational to human civilization on our fragile and burdened planet.

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