better account for the potential long-term consequences, we need to consider more carefully what the future may hold for the personal computer and the Internet in tandem.

Simply put, Zittrain's thesis is that although the Internet and personal computer are generative, both are at risk of becoming sterile. Paradoxically, the reason why both are at risk is their generativity. The very openness to unanticipated, unfiltered changes and innovation gives rise to the pressures for more controlled environments. A generative system does not mean that all changes or innovations will be good. Quite to the contrary, malicious spyware and computer viruses ("bad code"), among many other nasty things, emerge and proliferate alongside the beneficial innovations fostered in the uncontrolled and chaotic environment of generative personal computers and a generative Internet. Furthermore, the more visible, salient, and disruptive the bad code is, the less consumers and businesses appreciate the good and tolerate the chaos from which it came.

As such, for Zittrain the evolution of the Internet to a "network of control" and of personal computers to sterile appliances is underway. The former is seen in the current battle over network neutrality; the latter, in the proliferation of various "locked-down" end-user devices, which he calls "information appliances" (such as "mobile phones, video game consoles, TiVos, iPods, and BlackBerries"). Because consumers often are ill-equipped to deal with most of the harmful stuff—and, in fact, are often to blame because of "their own surfing or program installation choices"—they will increasingly look for gatekeeping, security, and regulation in the devices, technologies, and services they purchase. To better satisfy this demand and also enable devices to "call home" for updates, the appliances may be "tethered" to their suppliers by an Internet connection. This shift sterilizes the Internet and the personal computer, ostensibly at the consumer's request.

Yet Zittrain contends that even though sterilization might be responsive to consumer demand for a more stable and secure computing environment and prioritized services, it is undesirable. He offers three arguments to support this contention: The loss of generativity would affect innovation. Tethered appliances coupled with a network of control dramatically increase regulation of end-user behavior (by government and companies). And, based on his detailed discussion of Wikipedia, he suggests that generativity supports widespread participation and cooperation in cultural production and governance.

Zittrain's arguments that we ought to preserve generative personal computers and the generative Internet are provocative but seem incomplete. He recognizes that there would be opportunity costs but does not fully explain why generativity is worth preserving despite these costs. He does not engage in a structured analysis of the tradeoffs. His appeal to innovation, for example, seems insufficient because he makes no specific theoretic or empirical claims about the quality or quantity of innovation under different degrees of generativity. Such claims could and should be developed but, in fairness, require considerably more work (*6*). Zittrain's argument about increased regulation of user behavior is powerful, but it depends on his prediction of a complete shift to tethered appliances and controlled networks. To the extent that alternatives persist or hybrid scenarios emerge, it is not clear that his worst fears would materialize. (Of course, this means that sustaining alternatives is important.) Finally, with respect to his third argument, the relationship between generativity and participation and cooperation seems somewhat circular or, at least, underspecified (*7*). Though incomplete, these arguments merit serious attention and further development.

Zittrain make a number of recommendations about how to avoid heading off the cliff. One interesting suggestion involves porting and reconfiguring tools used at the content layer to encourage collective action—of the sort employed by Wikipedia and eBay, for example—to solve "bad code" problems and bring some stability to the Internet. That is, empower users to become part of the solution. Zittrain discusses a project he is involved with called StopBadware that is "designed to assist rank-and-file Internet users in identifying and avoiding bad code." The project allows users to contribute data about code running on their personal computers and potentially identify and mitigate security threats collectively. He also discusses a partnership between Google and StopBadware that identifies Web sites that have malicious code hidden in them and provides a warning to users in their search results. These are promising and innovative steps.

Whether these and the other prescriptions Zittrain discusses are necessary (or sufficient) to avoid a cliff dive is probably beside the point. The future of the Internet cannot be stopped, and it is unlikely to be either of the two extremes the author describes. He acknowledges this and begins to consider emergent hybrids that may involve the best or worst of the extremes. Most important, *The Future of the Internet* identifies and analyzes many of the key issues, obstacles, and tradeoffs that will define our future.

References and Notes

1. The book can be read and commented on at http://yupnet.org/zittrain/.
2. There is a rich literature on user innovation, e.g., E. von Hippel, *Democratizing Innovation* (MIT Press, Cambridge, MA, 2005).
3. R. Deibert, J. Palfrey, R. Rohozinski, J. Zittrain, Eds., *Access Denied: The Practice and Policy of Global Internet Filtering* (MIT Press, Cambridge, MA, 2008).
4. T. Bresnahan, M. Trajtenberg, *J. Economet.* **65**, 83 (1995).
5. P. Aghion, P. Howitt, *Endogenous Growth Theory* (MIT Press, Cambridge, MA, 1998).
6. This is a complex task. At either extreme, or anywhere in between, on the generativity scale (assuming such a scale could be constructed), innovation will occur; we should expect different profiles of investments, participants, objectives and motivations, innovations, and so on. Society might value the type of innovation that results from generative systems, but to what degree? At what cost? Compared to what? Etc. Zittrain does a good job of setting the stage for these questions.
7. For a recent examination of how the Internet enables user participation and cooperation in a variety of contexts and why encouraging such activities is socially valuable, see Y. Benkler, *The Wealth of Networks: How Social Production Transforms Markets and Freedom* (Yale Univ. Press, New Haven, CT, 2006); reviewed by B. Frischmann, *Univ. Chicago Law Rev.* **74**, 1083 (2007).

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GENETICS

Thoughts on Humane Genetics

Robert Pollack

Archibald Garrod, M.D., opened the field of medical genetics with his 1902 *Lancet* article, "The incidence of Alkaptonuria: A study in chemical individuality" (*1*). He first reported that the offspring of cousins expressed the phenotype of this genetic variant at a high frequency. From there, he leaped to the testable predictions that humans, like Mendel's peas, inherited this chemical difference as a pair of discrete "Mendelian characters" and that both parents had to contribute the variant "character" for the offspring to show the difference. Garrod saw even further than what we would call a recessive phenotype: he closed his paper with the insight that genetic variation of chemical structures from one person to another might explain the differences among us in many—perhaps all—other aspects of our appearance and behavior. His

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prescience was, however, not entirely modern. He had no explanation for the initial presence of any chemical genetic variation, and Darwinian natural selection was not in his toolkit of ideas.

Within a decade of Garrod's paper, the notion of scientific and medical intervention for the sake of improvement of the species or—as it was then called with portentous ambivalence—the "race," emerged fully formed under the flag of Francis Galton's neologism "eugenics." Could it not be that with our intellect, we might take charge of our species' future, weeding out some hereditable variants and seeding others so that humans as a whole might be quickly improved or even perfected? For seeding, or "positive eugenics," Mendelian genetics was seen by the eugenics movement as the source of advice for the guidance of young people about to marry and have babies. For weeding, or "negative eugenics," the genetic interpretation of family trees was to be the scientific rationale in the United States for governments, in service to the race, to examine, catalog, sterilize, incarcerate, and institutionalize large numbers of men, women, and children.

Charles Davenport was the guiding light of American eugenics, both positive and negative. In 1910, with funds from the widow of railway magnate E. H. Harriman, he established the Eugenics Record Office at Cold Spring Harbor, New York. There he and his superintendent Harry H. Laughlin kept files on hundreds of thousands of family trees, counseled the wealthy on how to protect their fortunes from bad germ plasm, wrote model eugenics laws at the request of state and federal authorities, and maintained warm collegial relations with the burgeoning eugenics movement in interwar Germany.

In 1911, Davenport laid out the agenda for American eugenics in *Heredity in Relation to Eugenics* (*2*), which became the standard textbook in U.S. universities. *Davenport's Dream* provides a facsimile of that edition, buttressed by short commentaries on topics that interested Davenport (such as the meaning of genetic variation, mental illness, nature versus nurture, and human evolution) from 12 leading genetics researchers. The volume, edited by two current members of Cold Spring Harbor Laboratory, Jan Witkowski and John Inglis, is important: well worth reading and well worth having for classroom instruction at any level from high school through graduate school, divinity school, medical school, or law school.

Davenport's Dream
21st Century Reflections on Heredity and Eugenics

by Jan A. Witkowski and John R. Inglis, Eds.

Cold Spring Harbor Laboratory Press, Cold Spring Harbor, NY, 2008. 520 pp. $55. ISBN 9780879697563.

I was somewhat surprised by the publication of this volume. When I was a senior scientist at the Cold Spring Harbor Laboratory in the early 1970s, Davenport and eugenics were not topics people there were interested in discussing—for good reason. Davenport's Eugenics Record Office contributed the scientific rationale for the restrictive U.S. immigration laws of 1924, which made it very difficult for those members of what Davenport called "the Hebrew Race" to escape to America from Nazi Germany a decade later. Approaching the book, I could not forget this nor the fact that my and my wife's ancestral families were for the most part killed in the Holocaust.

Yet because of the essays, I am pleased to recommend the volume to the broadest possible audience. Davenport's reprinted text may be thought of as an example of one of Stephen Gould's evolutionary "spandrels," that is, a scaffolding of now-useless information on which is built a novel and viable structure. In this case, the current viable and valuable structure is the set of commentaries. These elegantly summarize the state of medical genetics today, touching on aspects such as the Human Genome Project, ex vivo technologies of genetic selection, intentional variation and quick detection by reverse genetics, and the emerging understanding of the vast complexity of RNA-driven gene regulation by noncoding regions that rarely expresses itself as a "single gene" phenotype. The crucial question remains: in light of the disasters of eugenics, what is the proper use of what we know about human DNA?

The essays (especially those by Maynard Olson and Douglas Wallace, the editors' introduction, and James Watson's personal reflections) provide a firm foundation for answering that question: We are the products of natural selection working on inevitable, unavoidable genetic variation. That variation will never cease. The broadest possible definition of "normal" is the one closest linked to the realities of natural selection. No one can say which (if any) human genetic variants will survive the anthropocene epoch (*3*, *4*) we have just entered. Therefore eugenics was and remains a dead end, and it cannot be the answer.

Furthermore, whereas genetic science must not be used as an excuse to torture, punish, or in any way hurt a person, the findings from human genetics should be made available to alleviate individual suffering. Although eugenics proved a disaster, medical genetics has from its beginnings been a gift of the intellect from which every human might benefit—but the potential gains must be considered only one person at a time and, each time, only for that individual's benefit. Such a use of genetics does not attempt to imitate (and sharpen) Darwinian natural selection as eugenicists did. Instead, it intends to ameliorate natural selection's harshest decrees on members of our species. In laying out that difference with clarity and rigor, *Davenport's Dream* is a gift as well.

References

1. A. Garrod, *Lancet* **2**, 1616 (1902).
2. C. B. Davenport, *Heredity in Relation to Eugenics* (Holt, New York, 1911).
3. P. J. Crutzen, E. F. Stoemer, *IGBP Newsletter* no. 41, 17 (2000).
4. J. Zalasiewicz *et al.*, *GSA Today* **18**, 4 (February 2008).

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