Biohacking: The Beginning of the Biological Revolution

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The idea of a "hacker" was born 60 years ago and revolved around a nascent MIT computer science community. The term had no pejorative connotation; these "hackers" had no desire to break into computer systems or to steal credit cards. Early computer hackers were simply fascinated with the array of complex problems to be found in the new field of computer science [1]. Their motivation was not economic gain but rather the "hack" itself, the elegant application of technical prowess to solve new problems [2].

This early hacker ethic is appearing again today in garages, closets, and kitchens across the world. Instead of soldering circuit boards and programming in Fortran, today's hackers are splicing DNA and cloning bacteria. These biohackers, as they have been fittingly christened, seek to manipulate the building blocks of life, advancing knowledge and creating new life forms with novel uses.

The computer hacker movement sparked the computer revolution, exponentially increasing the pace of technological progress and permanently altering the societal landscape. The biohacker movement will have a parallel effect on biology-based technologies, fundamentally altering not only science but the human experience itself. The leaders of this paradigm shift will be today's biohackers.

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The Similar Pasts of Biohacking and Early Computer Hacking

The correlation between early computer hacking and the current biohacking subcultures is unmistakable. By aligning the development of these two fields we find that biohacking—defined as non-institutional research in bioengineering, a superset of synthetic biology—closely resemble the early stages of computer hacking.

Early computer hacking began in American universities; particularly relevant are the Massachusetts Institute of Technology; the University of California, Berkeley; and Carnegie Mellon University. With the development of the Internet, these independent communities grew more cohesive, and intercollegiate collaboration became possible. The development of the Jargon File in 1975, an early attempt to standardize hacker vernacular, marks the emergence of this institution-independent hacker community.

This progression from independent to multi-institutional communities is also evident in the development of biohacking [3]. Biohacking began in several primary institutions; the labs at MIT—some led by influential computer hackers such as Tom Knight—were particularly influential. The spread of biohacking can be traced through iGEM, the International Genetically Engineered Machine Competition. In 2004 the competition was an unnamed MIT-only event; in 2004 four schools attended the first-ever iGEM competition. In 2005 the event became international, and in 2010 MIT hosted 128 teams [4].

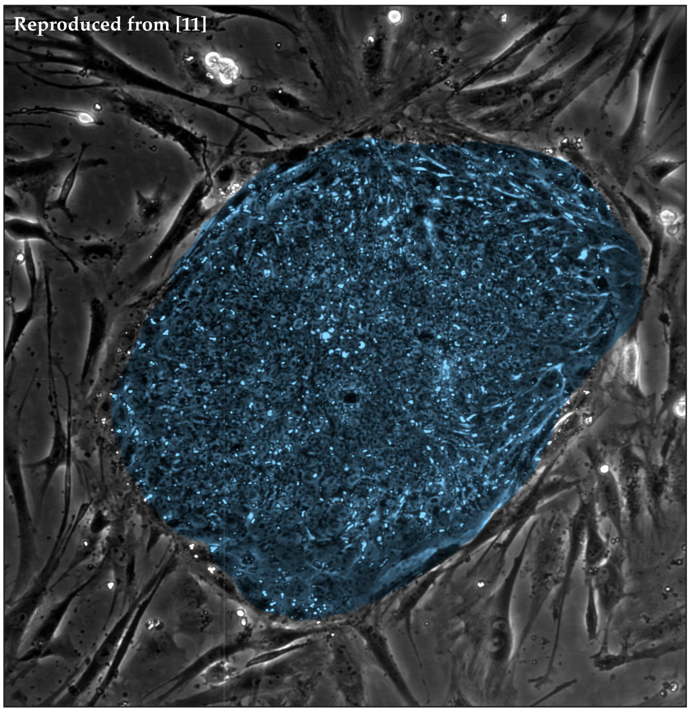
The next phase in the maturation of computer hacking and the current phase of biohacking was the spread from universities into the public sector. This vitally important shift was instigated by an increased availability of standardized computing components, which could be combined to form complex circuits and computers. Also instrumental was the spread of computer knowledge, evidenced by the formation of computer clubs such as the Homebrew Computer Club [5].

Analogously, the availability of necessary tools, coupled with the present standardization of biological parts, is currently pushing bioengineering into garages across the world, forming a global biohacker community. Biohackers can purchase used lab equipment online or create their own, often using publically available schematics shared by other enthusiasts. Synthetic DNA can be designed and purchased online for fewer than 30 cents per nucleotide, making custom genetic constructs easy and publicly accessible. Biohacker Tito Jankowski, Brown class of 2008, has developed an open source PCR machine, a costly but crucial DNA copier and manipulator, which can be built for $500. Bioengineering know-how is also becoming more accessible; examples of this trend include organizations such as DIYBio, which aims to unite biohackers and make "biology an accessible pursuit" [6], and BioCurious, which is making fully equipped lab space available to the public [7]. The standardization of biological parts is also underway, with the largest and most complete being iGEM's Registry of Standardized Parts.

The Future of Biohacking and Bioengineering

Biohacking is developing along a path startlingly similar to that of computer hacking, which speaks to the field's potential. This suggests that bioengineering will experience exponential progress and have a profound impact on the course of humanity, just as computer engineering has. Until this point, however, our analysis has been based on developmental correlation; why does bioengineering holds such potential, will the biological revolution really affect civilization to such a grand degree, and how will the biohacking community initiate this revolution?

The potential of the biological revolution is based on its machinery; the parts are biological, rather than metallic or electronic. This provides bioengineers with three advantages: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the parts already exist and have been honed over millions of years of natural selection, the "machines"—composite parts—are biological and thus integrate seamlessly with the human body and other life forms, and these machines are capable of self-replication.

The current developments in the field of bioengineering accent its potential even further; potential that is largely derived from the three factors discussed above. Genetic logic gates already exist, which, when combined, produce computational cellular networks and enable the intelligent engineering of cellular programs. These circuits direct custom information processing of input to result in a desired and predictable output. These cellular circuits of natural genetic regulation are now commonly rewired to achieve new functions; UC Berkeley scientists have designed yeast cells that produce diesel fuel via sugar fermentation [8]. The 2008 Brown iGEM team designed cells that detect heavy metals in drinking water, and stem cells have been manipulated to grow functioning human livers [9].

> "Today's biohackers will be tomorrow's technological leaders"

The expected trajectory of this work will result in custom cells with complicated, intelligently designed computational abilities that will use both natural and novel biological parts in unique ways, perhaps limited only by the creativity of the designer. For example, a synthetic cell that consumes carbon dioxide and produces energy is currently being developed. In the near future we can imagine "hacked" immune cells, programmed to detect and destroy early cancers, repair damaged organs, and even find and rapidly heal wounds. Soon, children may be injected with an array of life-enhancing cells that, once introduced, will live and multiply in the human body indefinitely.

As bioengineering progresses, the field will begin to feed on itself, accelerating the pace of progress exponentially, resulting in a true "revolution." Each discovery leads to an expansion of new discoveries and tools, just as the current generation of computers is used to design the next generation. This positive feedback loop has already begun. Due to recent advances in bioengineering, Gero Miesenböck's lab was able to create light-activated brain cells that grow into full, complete brains. Light can then be used to trigger neural activity, allowing for non-invasive manipulation and study of the brain, which has never before been possible [10]. This phenomenon of progress enabling progress, coupled with increasing computational abilities, will result in vast technological leaps.

The primary causative agent of this tidal wave of advancement will be the product of the current biohacking movement: the growth of non-institutional interest in bioengineering. The mechanism is simple and obvious; as non-institutional biology increases both in accessibility and possibility, more and more amateurs will be drawn into the field, increasing the pool of talent. Just as the leaders of today's IT industry were early computer hackers, so tomorrow's biotechnology leaders will be early biohackers. The growing field will swell again upon the arrival of for-profit bioengineering companies, the Apple and Microsoft of biology.

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The Importance of the Biohacking Movement

There are, of course, those who disagree with the potential of the biohacker movement. Many cite the cost of molecular biology, noting that fully equipped university labs typically cost hundreds of thousands of dollars. Jim Collins, a leading innovator in synthetic biology at Boston University, has cited the cost of molecular biology as a hurdle: "I'm not saying you need to be appropriately pedigreed, just appropriately resourced" [2].

While true, these arguments do not negate the potential of the biohacking movement, which lies not in the development of new technologies but in widespread exposure to the field of bioengineering. As a historical example, the Homebrew Computer Club did not result in any foundational advances in computer engineering; it was simply a place for early computer enthusiasts to share programming tips and to build early kit computers. It would be difficult to argue, however, that the club was historically unimportant, as it enabled the early development of Steve Jobs and Steve Wozniak, co-founders of Apple; Adam Osborne and Lee Felsenstein, creators of the first laptop; and Jerry Lawson, designer of the first cartridge-based video game system, among others. There is no sound reason to expect anything less extraordinary today when the computer is swapped for a pipette and PCR machine.

Conclusion

On the surface, the upcoming biological revolution may seem fantastical, but in a historical context it is to be expected. The biological revolution will continue to progress as the computer revolution already has; the biohacking culture, facilitated by decreasing DNA synthesis prices and increasing accessibility to bioengineering tools, will introduce many talented individuals to the field. This widespread exposure, combined with a positive feedback loop of progress enabling more progress, will result in the facilitation of unimaginable advances in technology. The introduction of cell phones, laptops, and microcontrollers have dramatically altered society; synthetic biological machines will bring the next generation of these ideas, improved through the advantages of polished parts, biological basis, and self-replication. Eventually, bioengineering will separate into two distinct fields: one—synthetic biology—which will specialize in combining existing biological parts to create new, unique functions, and the other—biological engineering—which will deal with the discovery and creation of new parts, just as electrical engineering has split into computer engineering and computer science. We've already seen this once; there is no reason to doubt the repetition of history: today's biohackers will be tomorrow's technological leaders. ■

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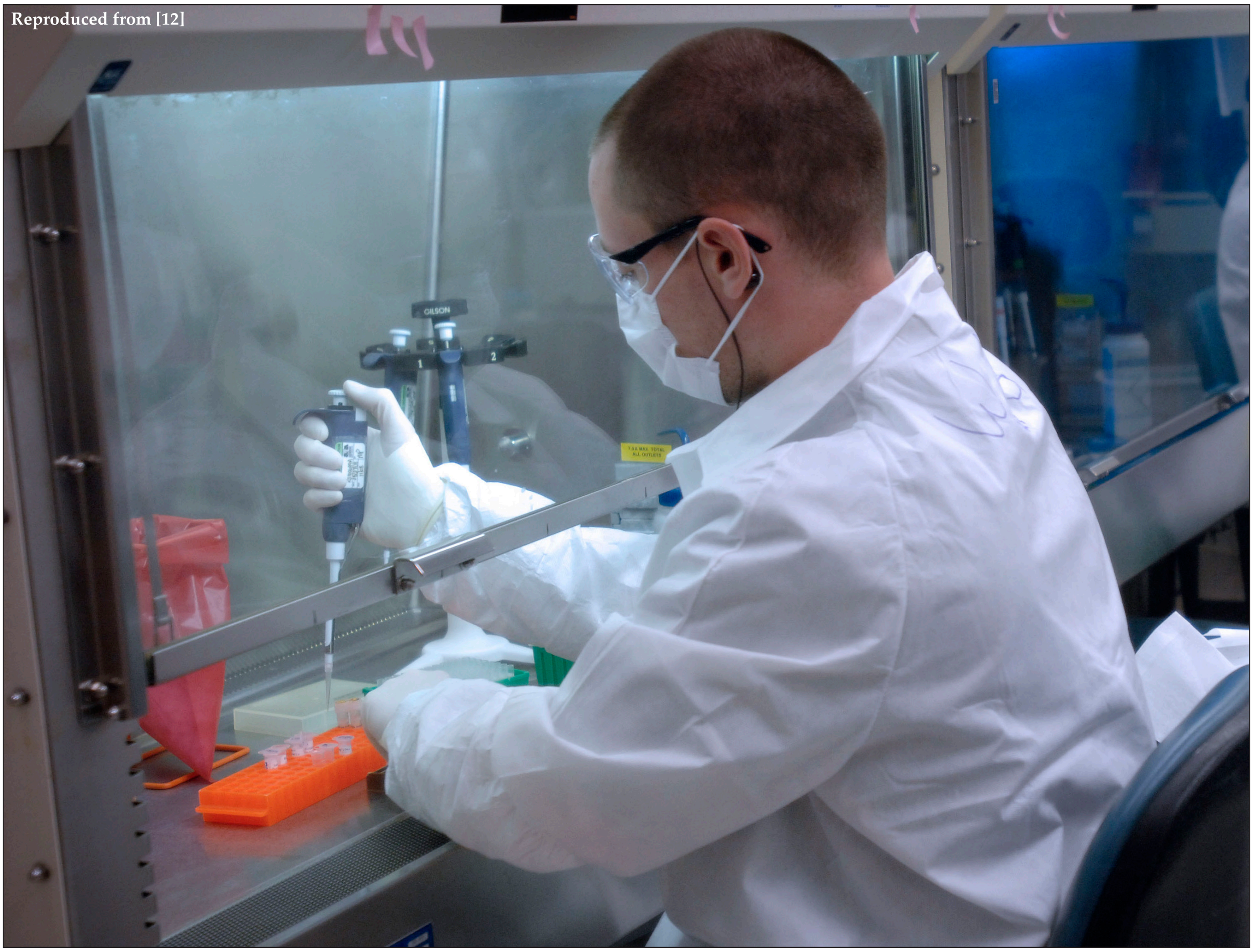
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