The next 25 years

Since this journal launched in March 1996, biotech has become a US economic powerhouse. To reach its full potential over the next 25 years, touching all corners of the globe, it must become more inclusive.

In biotech, past performance rarely predicts future results. Who foresaw CRISPR gene editing sweeping the world in 2012 or, for that matter, mRNA vaccines saving humanity? In the next 25 years, the watchwords must be “change” and “inclusiveness.” Biological technology has the potential to alter many aspects of human life, and it will transform them in ways we cannot imagine. But the ways we deploy biotech must change, too. Thus far, it has been a largely elitist enterprise, serving niche markets in rich nations. If biotech is not to be just another source of inequity in our world, it must redefine itself. That means focused, collective efforts to address the needs of patients and consumers—and of the planet.

Technologies for engineering, manipulating and monitoring living systems have come a long way since this journal launched in 1996. They have propelled biotech to one of the fastest-growing sectors of the US economy, contributing \$300–400 billion annually.

Sequencing has been part of that transformation. Today, sequencing a human genome takes just ~\$100 and a few hours—compared with the decades of effort and billions of dollars spent on the first three-gigabase genome. This means the DNA of an increasingly representative and diverse slice of the world's population will be sequenced: a million or so human genomes have been sequenced to date and 60 million genomes are projected by 2025, with another 100 million just in China by the decade's end. In tandem, smart devices and wearables will make mass phenotyping a reality. In the new era of human and holobiont real-world research, wearables and in-home sensors will provide longitudinal data, enabling detailed parsing of hitherto ill-defined states related to nutrition, health and disease. Crucially, it may also provide direction on how and when to intervene.

With DNA synthesis already a penny per base, bioengineers are moving from making small changes in single genes to writing and editing with precision throughout genomes. Through iterative design–build–test cycles, bioengineered products will become

increasingly sophisticated; indeed, some of the most complex metabolic pathways in nature have already been recapitulated through synthetic biology.

Not all areas of biotech will move quickly: we still manufacture proteins in Chinese hamster ovary cells, use ancient PCR technology in diagnostics, and make ethanol from corn. But the rate of knowledge expansion—and the rate of technology dissemination—is increasing every year. Digitization and virtualization of samples and findings in the cloud will allow ever larger datasets to be shared around the planet for analysis. Product development times will shorten, as they have for biopharmaceuticals and vaccines in this pandemic; new breeding and diversification technologies will accelerate crop development times. Cumbersome global supply lines for bulk manufacture of biotech products may be displaced by a shift to faster, distributed manufacturing.

Patients will be at the center of everything. Precision therapy will continue its slow march, but must practitioners must heed what people want: shorter treatments, oral or dermal drug formulations, and interventions for both quality and quantity of life. As populations gray, biopharma will have to expand beyond its preoccupation with oncology and rare disease to broader comorbidities associated with aging.

An urbanizing population—estimated to be 6.3 billion people (66% of the world) by 2050—will drive new biotech solutions for sanitary, microbe surveillance, and waste recycling systems. Efforts to slow the transmission of pathogens between populous urban centers (via air travel or otherwise) will necessitate the deployment of efficient detection systems for infectious agents.

In the face of threats from global warming, in farm fields, bioengineering will feed the growing global population through crops resistant to extremes of drought, cold, heat, salinity, pests and disease; in the lab, it will produce in vitro meat and alternative proteins. Fossil fuel-free routes will be bioengineered to a vast panoply

of chemicals, plastics, fuels, materials, flavorings and textiles.

As the dominance of the US biotech sector comes under increasing challenge, bioengineered products will spread more widely across the world. Innovative therapies from China will begin to compete with products from North America or Europe. A burgeoning pharmacopeia—supplemented with biosimilars and biobetters from China, South Korea and India—will drive down prices and increase usage; generic oligonucleotide therapeutics and gene therapies will follow. Emerging countries will similarly drive innovation in manufacturing, making products affordable not only for their domestic markets, but also for Latin America, Asia and Africa. China's ‘Belt and Road’ initiative will place it in a strong position to capitalize on links with the global South.

But the future of biotech is as much about political and cultural leadership as it is about the science and technology itself. In healthcare, premium-priced biotech products have exacerbated, rather than assuaged, long-standing health and wealth disparities in our societies. Most biologics are available to only a select few. In agbiotech, a lack of civil society dialog and the concentration of intellectual property within a few large corporations have brought bioengineered crops to a standstill in Europe and much of the rest of the world. For livestock engineering, the situation in the United States has similarly gone awry.

In the next 25 years, biotech must put people at its center. Today, the expertise walled off in academia or closeted in industrial franchises is in a bubble—cut off from the people it seeks to serve. The bioengineers of the future must not only promote technical excellence, but also foster equity, ethics, dialogue and social responsibility in how the fruits of their research are deployed. Only then can biotech become the “broad and inclusive enterprise” that will serve the needs of the many, rather than the few. □

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