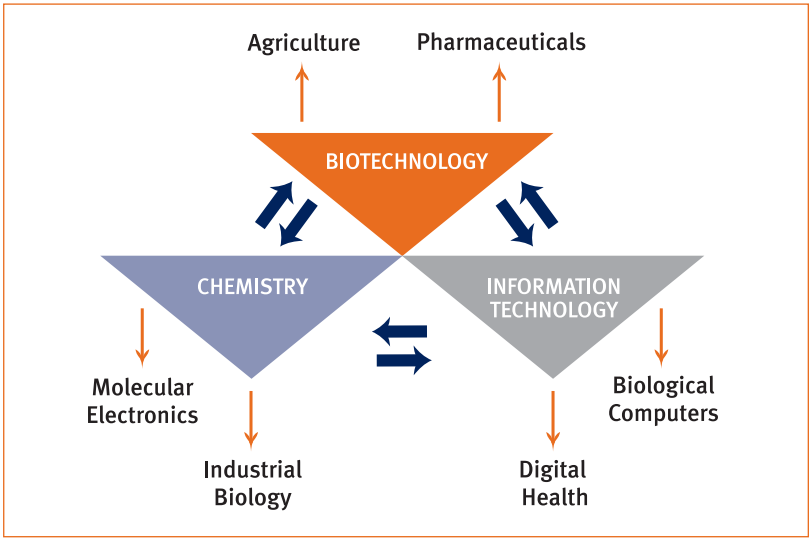
CONCLUSION

WHY FOCUS ON BIOFUTURES? AND WHY NOW?

In the coming decade, innovation will be driven by the fusion of biotechnology with a wide range of discrete industries. Companies that understand both the business and the science will be well positioned to anticipate and take advantage of opportunities as they unfold.

As the biotechnology industry matures towards predictive bioscience, stable regulation, sustainable business models, and effective products, integration is taking place with biotechnology and previously discrete, unrelated markets. This, in turn, is giving rise to new, hybrid companies and alliances. As shown in the figure below, the synergies between biotechnology, chemistry, and information technology are fueling innovation in many other areas, from the more traditional pharmaceutical, digital health, and agricultural industries, to such emerging industries as industrial biotechnology, molecular and organic electronics, and DNA and biologically based computers.

THE CONVERGENCE OF BIOFUTURES



From a technological perspective, the science of biology is transformative because it enables these innovations and provides a framework for cross-disciplinary efforts. The pace of scientific discovery across many fields is often driven by technological advances. Systematic structural descriptions precede important functional discoveries, and the increase in descriptive work carried out worldwide promise of the emergence of a mature biology. The underlying framework for theoretical biology that is developing concurrently in several fields promotes in-depth studies as varied as the modeling of full-body physiology and the simulation of molecular evolution. As biology moves from a descriptive to a predictive science, both the resolution and complexity of experimental questions and answers will continually increase. A growing number of companies are developing intentionally-designed products that capitalize on this evolving understanding and control of biological systems.

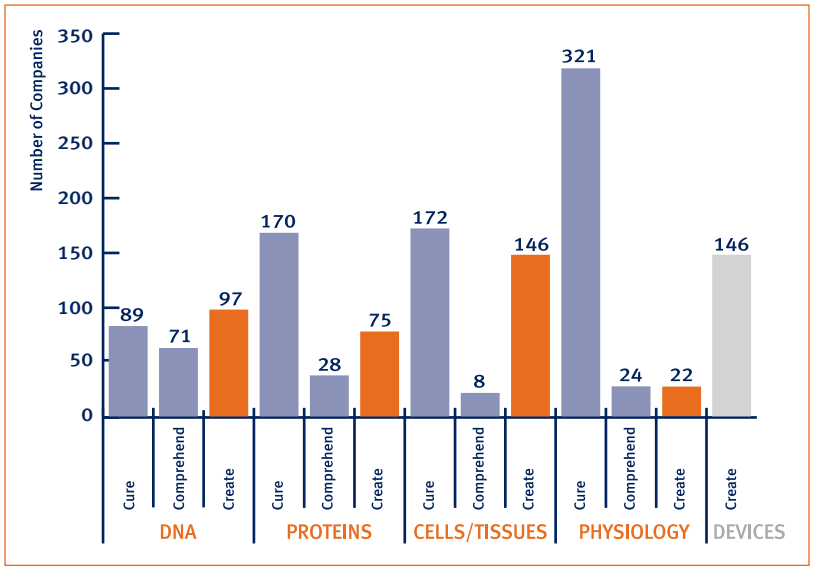
The global economic impacts of this integrated innovation could also be substantial. As biotechnology and bioengineered products are integrated into a wider variety of products and processes outside of the traditional drug markets, the biotechnology sector could evolve from a niche industry into a leading market, perhaps as large as aerospace and automobile manufacturing. Alternatively, the biotechnology industry could serve as a transformative technology that disrupts many leading market sectors, altering both the patterns of product manufacturing and consumption on a global scale. Much like the traditional telecommunication companies found themselves in unexpected competition with information technology and Internet companies, traditional pharmaceutical companies may find themselves suddenly competing with companies that manufacture, distribute, and market high-volume, unregulated bioengineered products.

THE SOURCES OF BIO-PRODUCT INNOVATION

Throughout the relatively short history of biotechnology, much of the investment and activities have focused on the development of drugs and therapeutic products comprising the "Cure" market space. More recently, attention has extended to the "Comprehend" or R&D arena, particularly with the high profile success of the Human Genome Project. But in the coming decade, the locus of innovation may well shift to the "Create" space, where companies in a variety of industries are leveraging all levels of biological organization.

More than 340 biotechnology companies are presently developing products and processes in the "Create" market space, where a creative, intentionally designed approach to product development is driven by the increasingly sophisticated tools and techniques of modern molecular biology, biochemistry, and genetics.

OVERALL DISTRIBUTION OF COMPANIES



CREATE SECTOR PERCENTAGE DISTRIBUTION

DNA	PROTEINS	CELLS & TISSUES	PHYSIOLOGY	DEVICES
20%	15%	30%	5%	30%

Nearly 100 DNA-based "Create" companies are building products ranging from genetically-engineered tools for gene expression and cloning to bio-optical systems for measuring and monitoring gene expression levels. On the research frontier, DNA is being explored for use as a biological computing system, and DNA molecules have also been used to assemble inorganic materials and to complete nano-scale electronic circuits.

More than 75 protein-based "Create" companies are synthesizing, purifying, and mass-producing proteins in biological factories. These proteins serve a variety of functions, such as the use of proteins as enzymes to catalyze chemical reactions, decreasing the need for high-energy, high-temperature, and/or high-pressure chemical processing. At the forefront of experimental bioscience, proteins and viruses are being used to coordinate the assembly of nano-scale electronic and optical devices.

More than 145 cell- and tissue-based "Create" companies are growing cells for purposes ranging from regenerative medicine (e.g., the production of stem cells) to the use of cells and tissues as controlled bio-manufacturing systems that efficiently grow specifically-designed DNA and proteins.

More than 20 physiology-based "Create" companies are developing microbiological cells and physiologically-engineered plants to produce biomaterials that could be used to build furniture, houses, and automobiles. And across several levels of biological organization, nearly 150 bio-device companies are integrating modern electronic and mechanical processes with biological materials to monitor and control those materials, both for diagnostic functions and as combination products for use as therapeutic medicines.

The growth of this "Create" segment is likely to accelerate because its products and processes are largely unregulated and the potential applications and markets are vast. Given the high costs and long timeframe required for drug development in the "Cure" space and the uncertain, often indirect, commercial potential of many discoveries in the "Comprehend" arena, it's reasonable to expect more companies in varied industries to enter the "Create" space directly or through alliances and joint ventures.

TOWARD A GREEN INDUSTRIAL REVOLUTION

The convergence and hybrid innovation described above have additional implications for traditional businesses born in the Industrial Revolution. In particular, biotechnology advances may significantly reduce the negative environmental impacts of processes for creating energy and manufacturing goods and materials.

Bioengineered products and processes could transform the energy industry by affecting both energy supply and energy demand. Biological processes could drive chemical reactions to create, transform, and store energy. Simultaneously, consumer use of biological and bioengineered products could alter patterns of energy consumption.

With respect to manufacturing, bioengineered products and processes can impact materials fabrication, device assembly, product use, and end-of-life recycling of products. Enzymes can be used to cost-effectively replace fabrication processes that require high heat, energy, or caustic chemicals. Biological processes can clean device surfaces prior to assembly, reducing the need for expensive solvents. Biological self-assembly could be leveraged to integrate and assemble products at small spatial scales, decreasing the cost and increasing the precision of assembly processes. Near the end of a product's life, enzymes and other biological molecules could be used to support the intentional degradation of organic components in appliances, cars, and other manufactured products, thereby increasing the efficiency of recycling and eliminating unneeded waste.

Likewise, the impact of biotechnology on the food and beverage industry may be substantial and multifaceted, affecting the production, packaging, distribution, and consumption patterns of food and beverage products worldwide. Bioengineered products and processes allow the design and integration of novel nutriceuticals and other biological and organic materials with more traditional food and beverage products. Bioengineered products can also transform manufacturing processes; as described above, enzymes could replace energy intensive "heat, beat, and treat" fabrication processes. Further, biological processes could clean fermentation, food, and beverage processing surfaces, again reducing the need for expensive solvents.

Clearly, a biotech-led green revolution would be a win-win situation—reducing damage to the environment and, in many cases, the costs of doing business as well.

BIOFUTURES IS HERE

BioFutures—the simultaneous convergence of biology and other sciences and multiple technologies—is well underway, and its transformative potential is substantial.

The pace and exact nature of innovation and acceptance will be affected by a wide range of economic, political, technological, and cultural forces. Weighing the risks and benefits will be an increasingly important challenge for CEOs and citizens alike. Developing a deeper understanding of the science, technology, and business of biotech is essential to make informed decisions and to seize opportunities that create value for both business and society at large.

Acknowledgments

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For more information about this document and on GBN's BioFutures research, meetings, and database please contact Chris Coldewey at coldewey@gbn.com.

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