Chapter Fifteen

THE INFORMATION REVOLUTION IS PART OF A BROADER TECHNOLOGY REVOLUTION WITH EVEN PROFOUNDER CONSEQUENCES

The information revolution is not the only technology-driven revolution under way in the world today, merely the most advanced. Advances in biotechnology and nanotechnology, and their synergies with IT, should also change the world greatly over the course of the 21st century.[1]

ADVANCES IN BIOTECHNOLOGY AND NANOTECHNOLOGY WILL ALSO GREATLY CHANGE THE WORLD

Developments in molecular biology since the discovery of the structure and function of DNA in the 1950s have established the knowledge base necessary to profile, copy, and manipulate plant, animal, and human genomes—the genetic basis for life. This enables a wide variety of powerful biotechnology techniques, including gene therapy, for the diagnosis and treatment of disease; designer drugs, tailored to target specific diseases; genetic profiling, to identify those susceptible to specific diseases; genetic identification, to aid in criminal and civil cases; genetically engineered biosensors, for a variety of applications; cloning, to artificially produce genetically identical organisms; and genetically modified organisms, to engineer specific properties into life forms for various reasons (e.g., foods with improved taste, artificially introduced nutrients, or longer shelf life; crops that are resistant to bugs, have in vivo pesticide protection, have greater yield, or grow in previously unproductive environments; and organisms that produce or deliver drugs for human disease control).[2] These powerful techniques will lead to many new products, services, and industries—and will render obsolete many existing

products and services. They will revolutionize human health care and make possible major improvements in agriculture. They should have a major impact on the world of the 21st century.[3,4]

Nanotechnology, broadly defined, includes microsystems, nanosystems, and molecular systems.[5] Over the past decade or so, major advances have been made in our ability to understand and control the fundamental building blocks of all physical things, at the micro-, nano-, and molecular levels, making possible integrated microsystems performing a wide variety of tasks, nanofabricated semiconductors that continue Moore's Law to ever smaller scales, molecular manufacturing in which objects are assembled atom by atom (or molecule by molecule) from the bottom up (rather than from the top down using conventional fabrication techniques), and novel nanoscale computers based on molecular electronics or quantum effects, to mention just a few of many possibilities. According to experts in this field, "these developments are likely to change the way almost everything—from vaccines to computers to automobile tires to objects not yet imagined—is designed and made," thereby having a major impact on the 21st-century world.[6]

THERE ARE MANY SYNERGIES BETWEEN IT AND THESE OTHER REVOLUTIONARY TECHNOLOGIES

Advances in information technology have enabled the data processing, storage, and retrieval capabilities necessary to map plant, animal, and human genomes; without these IT capabilities, the revolutionary biotechnology techniques mentioned above would not be feasible.

Likewise, advances in nanotechnology should make possible the continuation of Moore's Law to ever smaller scales, leading to evermore-powerful computers and memory storage devices of ever-larger capacities.

These are just two of many synergies that exist between information, bio-, and nanotechnologies.[7] As a result of these synergies, the overall economic and societal impact of this combined technology revolution will be even greater than that of the individual technologies.

THE CONSEQUENCES OF THE BIOREVOLUTION WILL BE ESPECIALLY PROFOUND AND QUITE CONTROVERSIAL

The ability to alter plant and animal genomes has already led to considerable controversy; the ability to alter the human genome will lead to enormous controversy.

Genetically modified crops are accepted and in wide use in some parts of the world (e.g., the United States) and rejected in others (e.g., Europe). Restrictions on the free movement of genetically modified crops throughout the world has already become a major international issue.[8] Likewise, the cloning of animals (e.g., "Dolly" the sheep) has become a major controversy in every nation in which it has been attempted.

But these controversies regarding the alteration of plant and animal genomes are nothing compared with the controversies that will arise over attempts to alter the human genome—to use genetic engineering techniques to "improve" the human species and clone humans—because this goes to the very heart of what it means to be "human." As one group of experts who have looked at this issue has said, "This will be a very controversial development, perhaps the most controversial in the history of mankind."[9]

AS WITH THE INFORMATION REVOLUTION, THE BIO- AND NANOREVOLUTIONS WILL PLAY OUT UNEVENLY THROUGHOUT THE WORLD

As time goes on and the revolutionary economic and societal consequences of biotechnology and nanotechnology begin to be realized, most likely at an uneven pace throughout the world, a study similar to this one will be called for, on the global course of the bio- and nanorevolutions and their regional variations.

NOTES

[1]This chapter is meant merely to introduce the reader to the existence and revolutionary potential of this broader technology revolution and provide some introductory references.

[2]This is an incomplete list. Antón, Silberglitt, and Schneider (2001) discuss these various biotechnology capabilities in considerable detail and provide extensive references to the relevant literature.

[3]In the view of Antón, Silberglitt, and Schneider (2001), "whereas the 20th century was dominated by advances in chemistry and physics, the 21st century will be dominated by advances in biotechnology."

[4]Enriquez (2001) presents a detailed vision of the profound economic and societal impact that the biorevolution will have throughout the world.

[5]Microsystems are assembled from micron-scale (i.e., 10^{-6} meter) elements. Nanosystems are assembled from nanometer-scale (i.e., 10^{-9} meter) elements. Molecular systems are assembled from individual molecules.

[6]The quote is from National Nanotechnology Initiative (2000), which discusses the potential of nanotechnology in some detail. Antón, Silberglitt, and Schneider (2001) also discuss nanotechnology in considerable detail and provide extensive references to the relevant literature.

[7]Antón, Silberglitt, and Schneider (2001), Enriquez (2001), and NSF/DOC (2002) provide detailed discussions of the many important synergies between these technologies.

[8]Enriquez (2001) discusses the controversy surrounding genetically modified crops and the significance of their acceptance or rejection for the future economic performance of nations.

[9]The quote is attributed to Antón, Silberglitt, and Schneider (2001), who estimate that we may have such human genetic engineering capabilities by 2015.