

## **‘Future Fundamentals’ – A World transformed by science and technology**

*By Peter Schwartz*

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Among the many forces reshaping the world today are two powerful drivers of change that will feed on each other. The first is the scientific and technological revolution that began 30 years ago; the second is the urgent need to deal with climate change. Indeed the scientific revolution is the most important tool—perhaps the only tool—we have for reducing the impacts of climate change.

In the early 1980s, advances like the discovery of the polymerase chain reaction (PCR), which enabled the replication of DNA, led to fundamental new capabilities in molecular biology and genetics. As a result, we have seen huge and continuing advances in biology and medicine. Similar revolutions in physics, chemistry, and mathematics have accelerated the expansion of the scientific frontiers. Those in turn have produced major technological advances ranging from smart phones to nanotechnologies.

As we look ahead, two scientific developments, among many, stand out as particularly significant in the near term. Both flow from the biological revolution. The first is regenerative medicine: growing new tissue to replace damaged parts of the body. Today if one has heart disease, a heart transplant may be the preferred therapeutic option. But people often die before finding a compatible heart from a recently deceased person, and even if they do, rejection can occur. Regenerative medicine will soon allow us to grow new organs like hearts, livers, and kidneys for people who need them from their own tissues. This means that most people will experience a long and youthful life as they replace aging and failing organs. Very soon we will also be able to inject stem cells into damaged hearts and brains hit by strokes in order to repair damaged tissues without even replacing the organs.

Related to regenerative medicine is human enhancement. We are going to make better people. But better in what sense? Better vision, hearing, endurance, size, metabolism, strength, and speed are among the many improvements that lie ahead. We are already taking small steps in that direction. I recently had cataract surgery to replace the lens in my left eye, which was becoming clouded and affecting my ability to read—one of my great delights. When the patch was removed on the morning after the 20-minute surgery,

my vision was perfect...even better than before the disease hit. With my high-tech dental implants and new lens I am well on my way to becoming a cyborg.

The second big advance we see coming is synthetic biology: the building of new and useful organisms. In the physical world, engineers have standardized parts, screws, bolts, and sheet metal that enable them to design and build new machines with relative ease. That means engineers don't have to start from scratch every time they want to design a car engine or a washing machine. Synthetic biology is about creating those capabilities in the world of biology.

This emerging area of research and development is mainly centered in places like the University of California. Nevertheless, practical products have already come out of the lab. The first is an e-coli bacterium that has been modified to produce an anti-malarial drug called artemisan. Scientists in the same laboratory are also working on a microorganism whose waste product is diesel fuel. In addition, Craig Venter, the biologist who first sequenced the human genome, is hard at work on a form of algae that will produce a variety of hydrocarbon fuels that will generate no net carbon dioxide. In fact, the algae will absorb CO<sub>2</sub> from the air to actually make the fuels. This is the beginning of a new industrial revolution.

Over the last two centuries, industry has advanced from manufacturing principally by hand to steam engines to electric motors. Each advance has ushered in huge productivity gains. Now, because of mounting concerns over climate change, we need clean production methods even more than increases in productivity. Previously, the objective was to make more from each hour of human labor expended. Now it is about making things with minimal environmental impact. Nature makes its organisms with no pollution; all waste becomes an input into something else. Nature's systems are fully integrated. Now industrial systems will function the same way nature does.

In the future, we will make more and more things using biological processes, radically reducing the amount of energy and materials needed to sustain a high standard of living. We may even end up creating electronic devices using biological processes. This shift has the potential to vastly expand wealth with little increase in pollution, resulting in a society that will look and feel very different as more bio-products hit the market. Synthetic biology is the key to making the next four billion people on Earth wealthy without destroying the planet's ecosystems.

These advances will also have a profound effect on demography. Population growth is rapidly slowing around the world as women move from the countryside to the cities. On the farm and in the villages, many children were needed; but in a city, more children become a costly disadvantage. Falling birthrates, combined with medical advances, mean that today's children may measure their lives not in decades but centuries. Indeed, by the time my 19 year-old son, Ben, turns 40, he is likely to be taking anti-aging drugs and

remain biologically 40 for a very long time. Moreover, children will become increasingly precious because, like all long-living organisms, we will tend to have fewer offspring. By mid-century the population of the Earth is likely to peak at around 9 billion and begin a downward trajectory to a sustainable population of two to three billion people.

Youthful old age is already beginning to affect the timing of retirement. About a decade ago, people began retiring later because they remained healthier longer while also realizing that they needed to keep working to build up sufficient pensions and savings to support their extended lifespan. So our future features a slowly growing but aging population that retires very late and lives long, youthful, and productive lives.

From industry to longevity to sustainability, the scientific revolution is—and will continue to be—transforming our world and our future.