ΦBK THE KEY REPORTER

A Global Garden in the 21st Century?

By Joel E. Cohen

THIS YEAR MARKS THE 200th anniversary of Thomas Robert Malthus's "Essay on the Principle of Population," which asserted that the human population grows exponentially. Many people think the human population has grown exponentially, but that is not so. An exponentially growing population always doubles in the same amount of time, like an interest-bearing savings account with a fixed compound interest rate. The human population doubled from perhaps one-quarter billion 2,000 years ago to a half-billion after 15 or 16 centuries. The next doubling took 2 or 3 centuries, and the population passed 1 billion around 1830. The next doubling took only 1 century, as the population passed 2 billion around 1930. The next doubling to 4 billion people took only 44 years.

Looking backward from today's population of nearly 6 billion, the most recent doubling of the human population took only 40 years. Thus, the doubling time of human population accelerated roughly 40-fold, from 16 centuries to 40 years. Never before the second half of the 20th century had any human being lived through a doubling of the human population, and now everyone who is 40 years old or older has seen the Earth's population double.

The past half-century saw another major demographic event that is also without precedent in human history. Around 1965 the population's growth rate peaked and began to decline. In the 14th century, a fall in the growth rate was caused by increased deaths from plagues, war, and famine. By contrast, the fall in the growth rate since 1965 has been caused by voluntary reductions in fertility. Although fertility in the rich countries has been falling for more than a century, the news in 1965 was the reduction of childbearing in the poor countries, where a majority of the world's people lived and live.

I offer these speculations to encourage us all to imagine a positive future we can work toward. The future is at least partially an object of choice, and not entirely (I hope) an inevitable outcome of an uncontrollable mechanical world.

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Pyramid of Population, Economics, Environment, And Culture

Why that colossal failure of prediction?

Let us think about population as one vertex of a symmetrical pyramid in which the other vertices are the environment, economics, and culture. Any corner can go on top. One

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reason no one foresaw the rapid rise in population and the fall in fertility after World War II is that our understanding did not, and still does not, encompass these four dimensions. Thinking in terms of this pyramid provides a checklist of crucial dimensions, although it will not eliminate uncertainty about the future.

This article offers some speculations about the future. These speculations, organized around the themes of population, environment, economics, and culture, are not intended to divert attention from today's serious problems—the poverty, malnutrition, illiteracy, disease, and indignity of life for billions of people, plus unprecedented physical, chemical, and biological perturbations of the planet. I offer these speculations to encourage us all to imagine a positive future we can work toward. The future is at least partially an object of choice, and not entirely (I hope) an inevitable outcome of an uncontrollable mechanical world.

Population and Society

Let's begin with population and society. A century from now, humankind will live in a global garden, well or poorly tended. Most people will live in cities, surrounded by large, thinly populated zones for nature, agriculture, and silviculture. Worldwide, between 100 and 1,000 cities of 5 million to 25 million people each will serve their inhabitants' wants for food, water, energy, waste removal, political autonomy, and cultural and natural amenities. Some cities will serve people who want to live only with people ethnically and culturally like themselves. Other cities will serve people who are attracted by ethnic and cultural diversity. Different cities will gain shifting reputations as being favorable for young people, childrearing, working, or retirement. The efficiency and quality of services that cities provide will depend on the quality of their managements and on the behavioral skills and manners of their populations.

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Just as feudal obligations were replaced by labor markets, other present rights and obligations will increasingly be replaced by markets. For example, there will be a worldwide market in permits for permanent residence in cities. The prices of these permits may be tacked on to real estate or rental prices. City managements will compete to command market rewards for the public goods they are able to provide. Countries like the United States that insist on a person's right to leave his or her country of birth will have to decide if that implies a person's right to enter some other country. Social and individual values will determine how far markets will be allowed to intrude into allocations previously determined by traditional means.

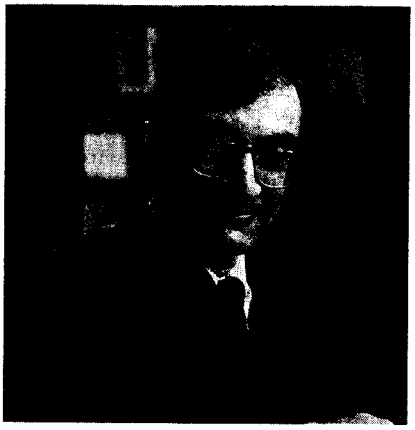

Photo by Robert Reichert, Rockefeller University

Joel E. Cohen

Women around the world will demand and receive education and jobs comparable to men's education and jobs. With better education and jobs, women will have increased autonomy and power in the family, economy, and society. Partly as a consequence of women's having attractive alternatives to childbearing and childrearing, the number of children that women bear in a lifetime will decline globally to the replacement level or below. As childbearing will occupy a falling fraction of most women's lengthening lives, women will intensify their demands for other meaningful roles.

Although global human population growth will end in the next century, some regions will be net exporters of people while others will be net importers. Rising pressures for migration from poorer to richer countries will strain traditionally xenophobic countries like Germany and Japan, as well as traditionally receptive countries like the United States, Australia, Sweden, and Argentina. Migrations will bring culturally diverse populations into increasing contact. The result will be many frictions as humans learn manners and tolerance. Intermarriages will make a kaleidoscope of skin colors.

The elderly fraction of the population will increase greatly, and the absolute numbers of elderly still more dramatically. Among the elderly, women will outnumber men by as much as 2 to 1. New social arrangements among the elderly will arise.

Environment

Now let's focus on the environment. The continental shelf, especially off Asia, will be developed to provide food, energy, and perhaps living space. Oceanic food sources will be largely domesticated. The capture of any remaining wild marine animals will be managed like deer hunting now.

The tropical forests that survive the onslaught of population growth and economic exploitation between 1950 and 2050 will be preserved as educational and touristic curiosities, like the immensely popular John Muir Woods north of San Francisco. Many forests will be meticulously managed for fiber, food, pharmaceuticals, and fun (that is, recreational exploration). Today's simplified agricultural ecosystems will be replaced by managed ecosystems of high complexity. Biological controls and farmer intelligence will maximize yields while nearly eliminating biocidal inputs like today's pesticides and herbicides.

Required agricultural inputs of nutrients and energy will be derived

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from human, animal, and industrial wastes rather than from today's fertilizers and fossil fuels. Unwanted effluents like eroded soil or agricultural runoff with pesticides and fertilizers will be eliminated or converted to productive inputs for industrial and urban use.

The atmosphere will also be managed. Rights to add carbon dioxide, methane, and other climatically significant trace gases and particles to the atmosphere will be traded in global markets for the services that natural ecosystems provide. Governments will recognize the potential of atmospheric and many other natural ecosystem services to generate taxes that can support other public goods. Gases will be manipulated as part of food production and wildlife management. For example, genetically engineered bacteria and farming practices will manipulate agricultural methane production.

People will revalue living nature as they realize that they do not know how to multiply old forests, coral reefs, and the diversity of living forms. People will increasingly value nature's genetic resources and aesthetic amenities. Conservation movements will gain renewed strength in collaborations with businesses.

The intensive management of continents, oceans, and the atmosphere will require massive improvements in data collection and analysis, and especially in our concepts.

A century hence, we will live on a wired earth. Earth, air, and sea will be continuously sensed. Like the weather stations on land and the satellites that now monitor the atmosphere, the oceans and solid earth crust of the next century will have three-dimensional lattices of sensing stations at all depths.

Mathematical models of earth, air, and sea will aim to predict major events such as El Niños, hurricanes, earthquakes, volcanoes, major plumes of hot water from oceanic vents, and shifts in major ocean currents. These models will improve with at least million-fold improvements in computing power over the next century. Models will integrate not only the atmosphere, crust, and oceans but also human and other biological populations, including domestic animals, trees, cereal crops, and infectious diseases; economic stocks and flows, including all natural resources; informational stocks and flows, including scientific, literary, artistic, and folk traditions; and familial, social, institutional, and political resources and constraints. Comprehensive models will include factors beyond human control, such as solar flares, and will represent, though not predict, human decisions.

Despite improvements in information, concepts, and management, the Earth will still bring surprises. Geophysical surprises will arise from an improved awareness of what the planet is doing, from inherent instabilities in geophysical systems described by the mathematics of chaos, and from rising human impacts. Surprising infectious diseases will continue to emerge from the infinite well of genetic variability. Historically, each factor-of-10 increase in the density of human settlements has made possible the survival of new human infections. As more humans contact the viruses and other pathogens of previously remote forests and grasslands, dense urban populations and global travel will increase opportunities for infections to spread.

The need for careful global management, trusteeship, or stewardship will become irresistible—particularly stewardship of living resources, human and nonhuman.

Economies and Culture

Now let's turn to economies, which will be increasingly integrated. Cities will concentrate the talent and resources required for international business. Hardly any complex product will be conceived, financed, engineered, manufactured, sold, used, and retired within the boundaries of a single political unit. Businesses will learn to profit from the eternity of atoms by designing products for use, return, and regeneration. Governments will find that a growing fraction of the power to control the economic well-being of their citizens lies outside their borders. Economic integration will give profit to those who can recognize the comparative advantage of other societies. Information will become increasingly valuable. Those who can create it, analyze it, and manage effectively on the basis of it will be at a premium. Information technology and global economic integration will grow hand in hand.

Culture pervades everything I have said about population, the environment, and economies. For example, culture conditions the productive and reproductive roles of men and women, defines which biological raw materials are seen as food and which are not, and shapes what consumers demand from the economy. Let us conclude with some speculations about the future of global culture.

An international common law—not a world government but rather international standards of behavior—will grow stronger and more comprehensive in a progression from technical, to commercial, to political law. International agreements on vaccination and on metric measures work because they benefit all who abide by them and many who do not. Growing investments by multinational corporations will force the development of international contract law.

Once the regional and global economic customs, institutions, and laws are firm, it will become too costly for nation-states or their successors to ignore them. Legal and economic resolutions of political conflicts will become more efficient than violent ones. Not all parts of the world will learn this lesson with equal ease.

As the peoples of Asia, Latin America, and Africa grow wealthier (too slowly, and with too many setbacks), their environmental fatalism and modest demands for food will be replaced by impatience with the accidents of nature, intolerance of environmental mismanagement, and refusal to eat less well than their neighbors. The definition of wealth may change toward one that is more information-rich and less material-

intensive. The need for careful global management, trusteeship, or stewardship will become irresistible—particularly stewardship of living resources, human and nonhuman.

Awe and Choice

Perhaps I am dreaming when I speculate that geophysical and biological surprises, the revaluation of living nature, our greater dependence on people all over the world, our growing determination to act lawfully, and our own aging (individually and as a population) will increasingly inspire in many of us a greater awe for the world, for others, and for ourselves.

The immense uncertainty of the future is the arena of human choice. A task for universities and their graduates is to provide the facts, theories, and people needed to achieve a prosperous, wired, well-tended, and beautiful global garden a century from now—a prospect, as Matthew Arnold put it, "which seems to lie before us like a land of dreams, so various, so beautiful, so new."

Universities and the thoughtful people they produce can help societies to understand populations, economies, environments, and cultures; to balance the goals of efficiency and equity; to improve the accounting of social well-being, of materials, and of the consequences of actions; and to illuminate the benefits that the well-off derive from helping the poor live better lives. When universities and their graduates seek imaginative new ways to address the natural constraints and the human choices that we, our children, and their children will face in the 21st century, there is hope. ■

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