Choosing Future Population

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How will the twenty-first century differ from the twentieth? The human population will probably be larger, more slowly growing, more urban, and older. Each of these changes is a result of human choices, individual and collective.

The human population nearly quadrupled from 1.6 or 1.7 billion in 1900 to more than 6 billion by 2000. The population passed 2 billion around 1927, 3 billion in 1960, 4 billion around 1974, and 5 billion around 1987.

The world had 6 billion people for the first time in history on Tuesday, October 12, 1999, according to the statistical agencies of the United Nations. The population clock maintained by the United States Census Bureau passed 6 billion people in July 1999. The Census Bureau and United Nations disagreed by three months because, in 1999, roughly 20 percent of the world's people had not been counted since 1990. Nobody knows precisely how many people had not been counted, because they had not been counted. The likely error in any estimate of the world's population is probably at least 120 million. The estimate of 6 billion on October 12, 1999, could be too high or too low by roughly the population of Japan. All that can be said with honesty is that, sometime around 1999, Earth's human population probably passed 6 billion people. By 2009, Earth's population was estimated at 6.8 billion.

It took hundreds of thousands of years from the origins of modern humans until 1927 to put the first 2 billion people on the planet. We added the most recent 2 billion in just 25 years. Never before the second half of the twentieth century had any human being lived through a doubling of the earth's population. Now, anyone 39 years old or older has seen the number of people double in his or her lifetime.

The next century will have billions more people in it. More young men and women than ever before are now entering the age of childbearing. Barring catastrophe, their children are likely to increase the world population by 1 billion to 4 billion people by the middle of the twenty-first century. No one can know precisely how many billions of people will be added because the future additions depend on current human choices about education, health, economics, peace and the environment. According to calculations of the United Nations Population Division, a difference of one child per woman from now to 2050 would make the difference between a world population in 2050 of 7.8 billion or of 10.8 billion—a difference of 3 billion people, as many people as there were in 1960.

In the next century, the human population will probably grow more slowly. For most of the last five centuries, including most of the twentieth century, the rate of growth of the human population was increasing. The all-time peak rate of growth, 2.1 percent per year, was reached around 1965. Since then, the population growth rate has dropped by nearly half, to 1.1 or 1.2 percent per year in 2009. The absolute increase in population peaked around 1990, when the number of human beings added each year rose to perhaps 86 million. Since then, the absolute increase has fallen to 75 to 80 million additional people per year. This rate of

increase is equivalent to about 150 added people per minute, the difference between 250 births per minute and 100 deaths per minute. While population growth is now slower than at its peak, it still vastly exceeds the estimated 10 million people who were added to the population each year at the beginning of the twentieth century.

For the first time in history, human reproduction is coming under human control. This self-control is still far from complete. Currently about half of all people live in countries where fertility is at or below the level required to replace the population in the long run. While more than half of all couples in developing countries now use contraception, hundreds of millions more do not because of poverty, lack of education, and lack of access. In the opulent United States, half or more of all conceptions are not intended.

The population growth rate is dropping so rapidly that some demographers think there is a better-than-even chance that the world's population will never double to 12 billion from its 1999 size of 6 billion people. Absolute population growth is very likely to slow further, and perhaps even to end. If that occurs, then the twentieth century was and will be the only century in the history of humanity to see a doubling of Earth's population within a single lifetime.

The twentieth century was the last in human history in which most people lived in rural areas. In Europe, widespread urbanization began in the eleventh century. Worldwide, urbanization has been taking place for at least two centuries but accelerated greatly in the twentieth century.

In 1900, no cities had 10 million people or more. By mid-century, one city did: New York. Today, there are 20 cities of 10 million people or more.

Population of the 25 Largest US Urban Places

1800	Population	1900	Population
New York city, NY	60,515	New York city, NY	3,437,202
Philadelphia city, PA	41,220	Chicago city, IL	1,698,575
Baltimore city, MD	26,514	Philadelphia city, PA	1,293,697
Boston town, MA	24,937	St Louis city, MO	575,238
Charleston city, SC	18,824	Boston city, MA	560,892

» See the complete table. (PDF)

Between 1900 and 2000, the number of city dwellers rose nearly 14-fold, from 200 million to 2.9 billion. Now about 50 percent of people live in cities, and nearly 10 percent of those city dwellers live in cities of 10 million people or larger, while roughly 51 percent live in cities of half a million or smaller. Almost all population growth in the next half century will be in cities, demographers expect. The world's rural population will remain flat near 3 billion people. In the twenty-first century, humanity will be predominantly urban.

In addition, the twentieth century will be most likely the last in human history in which younger people outnumbered older ones. During the past century, the proportion of children aged four years and under gradually declined, and that of people aged 60 years and older gradually increased. Each group constituted 10 percent of humanity in the year 2000. This convergence reflected improved survival and reduced fertility. Improved survival raised the average length of life from perhaps 30 years at the beginning of the century to more than 66 years at its end. Reduced fertility rates added smaller cohorts to the younger age groups. The aging of the human population, meaning a higher proportion of the population in elderly age groups, is likely to continue. According to a UN estimate, by the year 2050 there will be 3.3 people aged 60 years or older for every child four years old or younger.

All of these demographic changes result from choices by individuals and societies. They are not inevitable outcomes of a mechanistic world. How much we invest in public health and biomedical research, how many children we decide to have, where we choose to live, and whether we settle our differences peacefully or violently all strongly influence whether the human population of the coming century

will be larger, more slowly growing, more urban, and older.

The human population will interact in the twenty-first century with dramatic economic changes. Three of these changes could, if we so choose, take place in information technology, biotechnology, and economic inequality.

In 1900, automated information processing was largely limited to the use of punched cards to control looms. By 1950, a very few general-purpose digital computers had been developed to wage war. Today, personal computers are abundant in homes and landfills. Microprocessors tend quietly to domestic, commercial, industrial, and military appliances. What should we expect in the twenty-first century? Consider the history of plastics. Until 1909, when Leo Hendrik Baekeland patented Bakelite, plastic was expensive and rare. In 1997, we humans used 130 billion kilograms of plastics—nearly 22 kilograms for every man, woman, and child. Before the end of the next century, we will be equally saturated by information technology. Microprocessors will be as ubiquitous and disposable as plastic bags are today. Microprocessors will improve security, transport, sanitation, and energy efficiency in cities. They will continuously monitor the health and safety of people and the status of the environment. They will carry out a significant fraction of the scholarly, scientific, artistic, and professional work that humans perform today—and they will do it better. The twenty-first century will be saturated by information technology, with all its potential for control and liberation.

The biotechnology of the twenty-first century will be at least as revolutionary as the information technology. In 1900, scientists rediscovered the 1865 experiments of Gregor Mendel and established the chromosomal basis of genetics. In 1944, experiments done at the Rockefeller University in New York showed that DNA was the genetic material. In 1953, Watson and Crick discovered the chemical structure of DNA. In 1995, the first completed genome of a non-viral self-replicating organism, *Hemophilus influenzae*, was published. We now have a nearly complete description of the three billion nucleotides of human genomes, as well as complete genomes of plants. Biotechnology will progressively become cheap and universal. It will permeate medicine, agriculture, food processing, forestry, and fisheries if people choose to permit it. Less obviously, biotechnology will transform mining, as microorganisms are engineered to extract and concentrate desirable minerals, and waste disposal, as microorganisms are engineered to degrade undesirable waste products. Biotechnology will transform manufacturing as we learn to grow, rather than to make, new materials and products. Biotechnology in combination with nanotechnology will transform military strategy. Biotechnology in combination with information technology will revolutionize our basic understanding of biology. Like the revolution in atomic energy which preceded it, and like the revolution in information technology that accompanies it, the revolution in biotechnology contains potentials for both the corrosion and the fulfillment of basic human values. We have to make individual and collective choices.

A third plausible and possible economic change, after information technology and biotechnology, is diminished economic inequality. During the twentieth century, the average annual gross domestic product per person more than quadrupled, to $5,200. The aggregate world economy grew sixteen-fold. But the world's people shared very unequally in the rising incomes. Between 1870 and 1985, the ratio of average incomes per person in the richest countries to incomes in the poorest countries increased six-fold. Adjusted for purchasing power, in 1997 the poorest 2 billion people had incomes of $1,400 per year—less than one-sixteenth the average incomes of the richest billion. So despite unprecedented economic growth, most of the world's people lived in poverty in the twentieth century.

In the future, if the globalization of the economy continues; if the rich countries see their self-interest in making most poor countries become richer; if the spread of effective democratic governments continues; and if the political and religious cultures of rich and poor countries permit an integrated global economy to make constructive use of information technology and biotechnology, the poor parts of the world could continue to catch up with the rich countries, as China and India are now doing.

The twenty-first century's demographic and economic possibilities hold the potential for major cultural changes in education and the status of women.

In the twentieth century, primary education spread across the world. In 1900, almost no children went to primary school in much of Latin America, the Caribbean, East Asia, and Southeast Asia. Now primary schooling is nearly universal in these regions as well as in Western Europe and North America. Still today, only three-quarters of the children eligible to attend primary schools in developing countries do so. The highest proportions and numbers of children are out of primary school in South Asia and sub-Saharan Africa. The roughly 100 million children who are out of primary school are disproportionately girls, and are mainly illiterate.

Demography poses big challenges to education in the first half of the twenty-first century. The number of children of school age (roughly 6 to 16 years old) will drop by a quarter in today's more developed countries. The number of children of school age will rise by more than 70 percent in today's least developed countries over the next three decades, despite rapidly falling global population growth rates. The countries with the least means will face the most rapid growth in the numbers of school-age children. If people choose to make it so, all children could complete primary and secondary schooling of vastly better quality than is now offered. Universal basic and secondary education could transform the twenty-first century.

A second cultural change in the twenty-first century, in addition to the continuing spread of education, will be the improved status of women. Women won the right to vote in the United States in 1920. The United Nations Commission on the Status of Women was formed to monitor and enhance the situation of women in 1946. Yet by 1991 fewer than 5 percent of the world's heads of state, of major corporations, and of international organizations were women. More change was apparent for the mass of women than among the elites. Worldwide, female participation in the cash economy, relative to men, nearly doubled in a generation. In 1970, the labor force had 37 women per 100 men. In 2007, the labor force had about 67 women per 100 men (1.2 billion of a total world labor force of 3.0 billion).[1] The developing regions saw the largest increases in paid work for women. If primary and secondary education is extended to all children in the twenty-first century, the status of women will continue to improve.

In addition to changes in education and the status of women, other equally important cultural changes will probably include the spread of international law in association with, and partly driven by, the spread of market economies and democracy. This list of important changes does not claim to be complete.

Thus far, I have proposed nine differences between the twentieth century and the twenty-first:

Demographic changes	1. Larger population size
	2. Slower population growth
	3. More urbanization
	4. Aging
Economic differences	5. Information technology
	6. Biotechnology
	7. Reduced economic inequality
Cultural changes	8. Universal basic and secondary education
	9. Enhanced status of women

A tenth difference will be major changes in the relationships between humans and our physical, chemical and biological environment.

The human species is embedded in a network of relationships with other biological species and mineral species (notably water, oil and metals). Some of these relationships are purely esthetic, as when we admire a beautiful bird, butterfly, diamond, rainbow or waterfall. Other relationships are more immediately practical. Among the practical relationships, the feeding relationships among species are particularly important.

Humans eat thousands of other living species. Tens of thousands of species eat us. Lions and tigers were the terror of earlier humans. Today the terrors are more often microbial. Thousands of species of bacteria reside in our guts, eagerly

responding to every meal we feed them. Every human body contains roughly ten times as many bacterial cells as human cells, so a human's metabolism is roughly 90 percent bacterial. Hundreds of species of fungi reside on our skin. Insects bite us. When we are unlucky, hostile microbes infect us as we breathe or as we are bitten.

The applied science that manages the species we eat is called agriculture. The applied science that manages the species that eat us is called public health and medicine. Both applied sciences operate on principles that have been or will be elucidated by the basic science of ecology and population biology.

The ecological term for the network of feeding relations among species is a food web. A food chain is one pathway through a food web, for example, from one species of grass to cows to humans. A food web is the entire network of food chains, including all grasses, herbs and forbs, all herbivores in addition to cows, and all carnivores and omnivores in addition to humans, as well as all decomposers and scavengers. In short, a food web is a chart of which species eat which other species in an ecological community.

Herbivore:	An animal that feeds chiefly on plants.
Carnivore:	An animal that eats flesh.
Omnivore:	An animal whose normal diet includes both plants and animals.

If the global food web is envisioned as a spider web, with one biological species at each intersection of strands, and with strands representing food flowing between pairs of species, then the growth of the human population and its capacity to shake the global food web in the twentieth century could be envisioned as replacing a spider by a tiger. During the twentieth century, humans' aggregate impacts on biotic and geological processes grew enormously. Human-induced emissions of carbon to the atmosphere grew from 0.5 billion tons to 7.3 billion tons per year. World water withdrawals from all renewable freshwater sources grew eightfold from 1900 to roughly 4,000 cubic kilometers per year by 2000. Emissions of nitrogen from the combustion of fossil fuels grew twenty-fold, to 25 million tons per year.

These enormous human effects on the environment had consequences. The concentration of carbon dioxide in the atmosphere increased by about 20 percent. Today's level is higher than at any time in the last 150,000 years, a period that includes the emergence of modern humans and the inventions of agriculture. Humans now withdraw annually roughly a quarter to half of all available renewable freshwater. Another eightfold increase cannot happen in the twenty-first century. The mass fraction of nitrates in ice grew from 45 parts per billion at the beginning of the century to 120 parts per billion at the end. Human activities account for 40 percent of the nitrous oxide, 70 percent of the ammonia, and at least 80 percent of the nitric oxide emitted to the atmosphere from all sources.

Human interventions in global processes have grown faster than our understanding of the likely consequences of these interventions. Nature, in turn, has surprised us. Chlorofluorocarbons created ozone holes. The Aral Sea shrank from the fourth to the eighth largest lake in the world. Human immunodeficiency viruses, antibiotic resistance and mad cow disease emerged. Malaria, tuberculosis, cholera and other ancient scourges grew strong again.

The history of atmospheres and oceans shows that abrupt changes could occur in the coming century or centuries. These abrupt changes could disrupt the physical and biological setting of human societies. The future of many natural systems and their future effects on us depend in part on how well we come to understand our options, and what we decide to do. In the twenty-first century, the human enterprise is no longer small compared to the size of the Earth. The future condition of our environment is at least partly a consequence of the choices we have made and will make.

In human terms, almost nothing is inevitable about the twenty-first century. For example, urbanization offers exciting opportunities for educational and cultural enrichment. Urbanization also threatens frightening hazards from infectious diseases unless adequate sanitary engineering supplies clean water and removes wastes. People may choose to have more or fewer children than anticipated, to

pursue or to abandon biotechnology, to educate all children or not, to protect non-human species or extinguish them. A healthy aging population offers unprecedented opportunity for longer use of acquired skills and experience, but threatens to bring unprecedented numbers of abandoned oldsters unless we anticipate the consequences of differently constructed families. Our new technologies can add to or reduce human perturbations of the environment.

Until we understand better the interaction between humans and our planetary home, we will not be able to choose how the natural world will treat us. Surprises from the natural world will continue. We are making choices about our future every day. How much we invest in better understanding of those choices and their consequences is also a choice.

Our health and well-being depend on managing well and wisely the species that eat us, the species we eat, and above all ourselves. What happens to the human population in the coming century will strongly affect the planetary food web. What happens to the planetary food web in the coming century will strongly affect what happens to us humans.

Guiding Student Discussion

Many people think, incorrectly, that the human population of Earth has been growing exponentially. Exponential growth is defined as the growth that results from a fixed annual percentage increase, like a savings account with a constant rate of compound interest. Exponential growth implies that the time required to double the human population is constant, regardless of the absolute size of the population. Contrary to the prediction of exponential growth, doubling times of the human population of Earth have not been constant. The human population took fifteen or sixteen centuries to double from roughly a quarter billion people two thousand years ago to half a billion around 1500, when Europeans first went to the New World, about 300 years to double from half a billion to 1 billion (around 1800-1830), roughly one century to double from 1 billion to 2 billion (1800-1927) and fewer than 50 years to double from 2 billion to 4 billion (in 1974). Until the late 1960s or early 1970s, the pattern of growth of Earth's human population is best described as super-exponential (faster than exponential). Since roughly 1965-1970, the growth rate of the human population has declined by nearly half, from its high of 2.1% per year to the present level near 1.1% per year.

Ask members of your class who are skillful with calculators to calculate how long it would take the Earth's population to double at a growth rate of 2.1% per year (the peak growth rate, circa 1965), and how long it would take Earth's population to double at 1.1% per year (the growth rate circa 2009). Then ask them to compare these estimated doubling times with the historical doubling times before the twentieth century. In the sense that the present doubling times are much shorter than historical doubling times before the twentieth century, the rapid growth of parts of the human population has not ended (although some national populations have ceased growing or begun to decline).

Discuss with students some of the factors responsible for the acceleration of population growth up to 1965: an improved food supply in the Old World resulting from foodstuffs of the New World (e.g., corn, potatoes; what others?) and from increased land per person, the industrial revolution of the nineteenth century, the invention of antibiotics and sulfa drugs and inexpensive public health measures in the twentieth century. Discuss with students some of the factors responsible for the decline in the rate of population growth from 1965 onward: the improved survival of children (making it unnecessary for parents to have many children in order to assure surviving offspring to care for parents in their old age), improved literacy and job opportunities for women, rapid urbanization (which changes children from valuable helpers on the farm to individuals who require expensive urban housing and education), and the widespread availability of modern contraceptives. Ask your students to consider what other factors may have affected both the acceleration and the deceleration of population growth.

Ask your students to scan a newspaper or news website for a week looking for examples of interactions among population, economics, environment, and culture.

For example, are housing developments in your area converting land from agricultural to residential uses? Where this encroachment is occurring, how much is due to population growth and how much is due to economic change? Are some individuals concerned about the economic and cultural consequences of large-scale immigration?

Ask students with ecological interests to keep a list for a week of all the different biological species in their diet. For example, a hamburger on a bun with mustard includes: beef cattle, wheat, sugar, yeast (in the bun), mustard seed and the source of the vinegar in the mustard sauce. If the hamburger has ketchup and pickles, then tomatoes and cucumbers (and what other spices?) are part of the diet. Take a careful look at the ingredients of a cereal box.

If a hamburger has a quarter pound of beef, and if every one of the 6.8 billion people in the world consumed one hamburger every day, then the world's people would consume 1.7 billion pounds or 850,000 tons of beef daily or more than 310 million tons of beef annually. Students who wish to pursue this question further could go to the web site of the United Nations Food and Agriculture Organization to find out the annual production of beef, poultry and other meats and grains. In 2008, the estimated global bovine (beef and similar) meat production of the world was 65.1 million (metric) tonnes or nearly 72 million American tons. What are the implications? Given the production figures, is everybody in the world eating the equivalent of one hamburger a day?

Other sources that may be of interest

1. Joel E. Cohen, *How Many People Can the Earth Support?* (1995) A scholarly analysis of population issues and all their complexities. The definitive work on the global population problem. –Edward O. Wilson, Harvard University
2. Matthew Connelly, *Fatal Misconception: The Struggle to Control World Population* (2008). A highly regarded reference work on the population-control movement.
3. Paul R. Ehrlich and Anne H. Ehrlich, *The Dominant Animal: Human Evolution and the Environment* (2008). A historical discussion of the relationships and difficulties between environmental change and genetic and cultural evolution.
4. Robert Engelman, *More: Population, Nature, and What Women Want* (2008). An exploration of the history and relationships between population, women's autonomy, and the natural world.
5. Massimo Livi-Bacci, *Concise History of World Population: An Introduction to Population Processes* (2001). A history of world population, investigating the links between nature, culture and population and thereby to look at ways of preventing future environmental collapse and human catastrophe. –from the publisher
6. Ben J. Wattenberg, *Fewer: How the New Demography of Depopulation Will Shape Our Future* (2005). In developed and developing countries around the world, birth and fertility rates have begun to fall at an astonishing rate unprecedented in human history. . . . explores the implications of a declining population for geopolitics, the environment, and the world economy. –Book News, Inc., Portland, OR
7. http://www.un.org/esa/population/unpop.htm is the home page of the United Nations Population Division, a source of generally reliable demographic information.
8. http://esa.un.org/unpp/index.asp gives access to the United Nation Population Division's online database and projections of future population according to the latest revision.

Endnotes

[1]Global Employment Trends for Women, March 2008, International Labour Office, Geneva, Switzerland. (PDF)

Joel E. Cohen earned his B.A., summa cum laude, from Harvard University in 1965. He

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Dr. Cohen was a MacArthur Foundation Fellow and is a member of the National Academy of Sciences, the board of directors of The Nature Conservancy, and the board of trustees of the Population Reference Bureau. He shared the Tyler Prize for Environmental Achievement in 1999 and the Fred L. Soper Prize of the Pan American Health Organization, Washington, DC, in 1998 for work on Chagas disease.

Address comments or questions to Professor Cohen through TeacherServe "Comments and Questions."

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