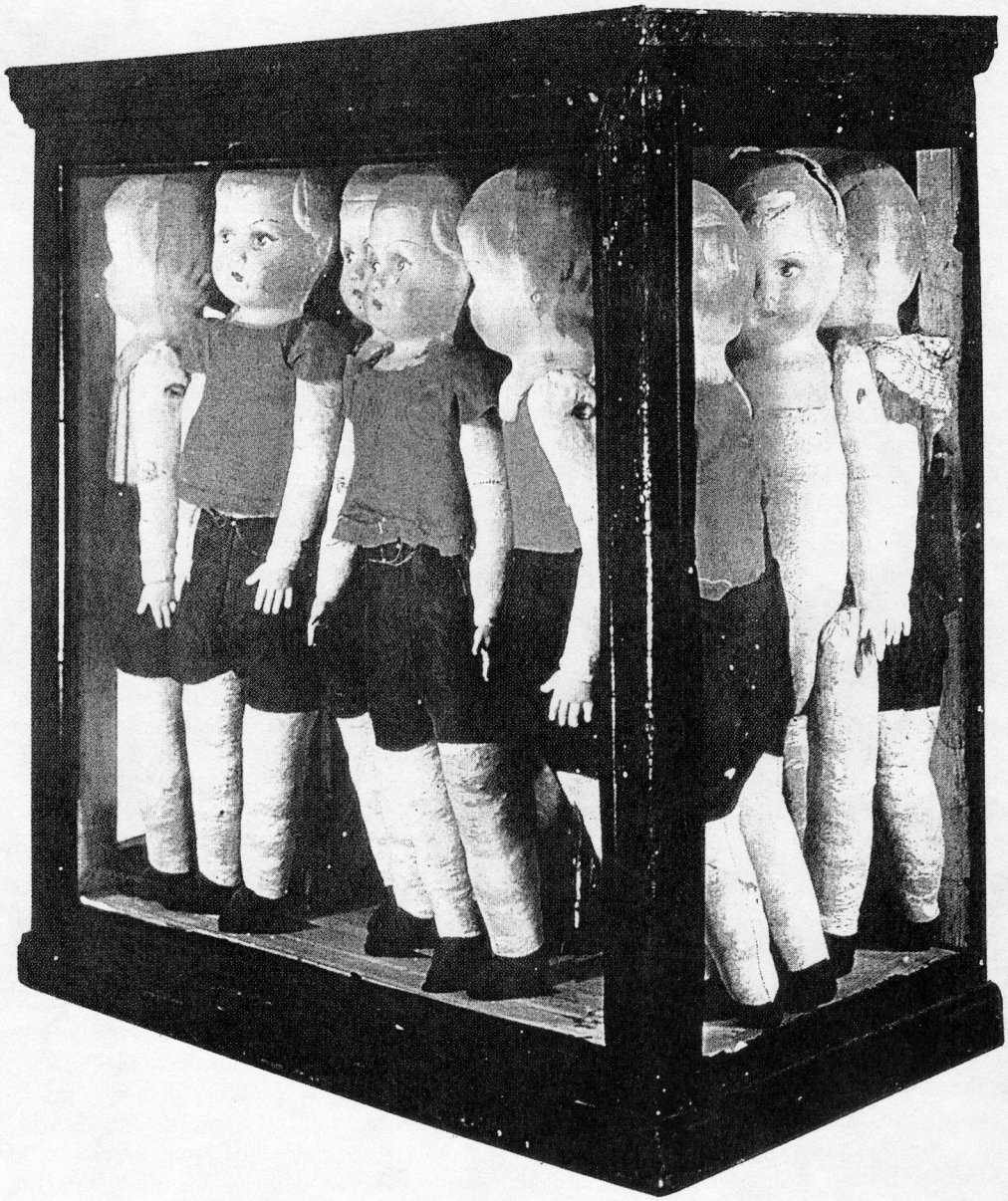
How Many People Can the Earth Support?

The answers depend as much on social, cultural, economic and political choices as they do on constraints imposed by nature

BY JOEL E. COHEN



Arman, Village of the Damned, *1962*

ON APRIL 25, 1679, IN DELFT, HOLLAND, the inventor of the microscope, Antoni van Leeuwenhoek, wrote down what may be the first estimate of the maximum number of people the earth can support. If all the habitable land in the world had the same population density as Holland (at that time about 120 people for every square kilometer), he calculated, the earth could support at most 13.4 billion people—far fewer than the number of spermatozoans his lenses had revealed in the milt of a cod.

In subsequent centuries, van Leeuwenhoek's estimate has been followed by dozens of similar calculations. Around 1695 a Londoner named Gregory King estimated that the earth's "Land If fully Peopled would sustain" at most 12.5 billion people. In 1765 a German regimental pastor, Johann Peter Süssmilch, compared his own figure (13.9 billion) with the estimates of van Leeuwenhoek, the French military engineer Sébastien Le Prestre de Vauban (5.5 billion) and the English writer and cartographer Thomas Templeman (11.5 billion).

In recent decades estimates of maximum population have appeared thicker and faster than ever before. Under the rubric of "carrying capacity" they crop up routinely in environmental debates, in United Nations reports and in papers by scholars or academic politicians trained in ecology, economics, sociology, geography, soil science or agronomy, among other disciplines. Demographers, however, have been strangely silent. Of the more than 200 symposiums held at the 1992 and 1993 annual meetings of the Population Association of America, not one session dealt with estimating or defining human carrying capacity for any region of the earth. Instead, professional demographers tend to focus on the composition and growth of populations, restricting their predictions to the near term—generally a few decades into the future—and framing them in conditional terms: *If* rates of birth, death and migration (by age, sex, location, marital status and so on) are such-and-such, *then* population size and distribution will be so-and-so.

Such conditional predictions, or forecasts, can be powerful tools. Projections by the U.N. show dramatically that *if* human populations continued to grow at 1990 rates in each major region of the world, *then* the population would increase more than 130-fold in 160 years, from about 5.3 billion in 1990 to about 694 billion in 2150. Those figures are extremely sensitive to the future level of average fertility. If, hypothetically, from 1990 onward the average couple gradually approached a level of fertility just one-tenth of a child more than required to replace themselves, world population would grow from 5.3 billion in 1990 to 12.5 billion in 2050 and 20.8 billion in 2150. In contrast, if (again hypothetically) starting in 1990 and ever after couples bore exactly the number of children needed to replace themselves, world population would grow from 5.3 billion in 1990 to 7.7 billion in 2050 and would level off at around 8.4 billion by 2150.

The clear message is that people cannot forever continue to have, on average, more children than are required to replace themselves. That is not an ideological slogan; it is a hard fact. Conventional agriculture cannot grow enough food for 694 billion people; not enough water falls from the skies. The finiteness of the earth guarantees that ceilings on human numbers do exist.

Where are those ceilings? Some people believe that any limit to human numbers is so remote that its existence is irrelevant to present concerns. Others declare that the human population has already exceeded what the earth can support in the long run (how long is usually left unspecified). Still others concede that short-term limits may exist, but they argue that technologies, institutions and values will adapt in unpredictable ways to push ceilings progressively higher so that they recede forever. The differences of opinion are buttressed by vast disparities in calculation. In the past century, experts of various stripes have made estimates of human carrying capacity ranging from less than a billion to more than 1,000 billion. Who, if anybody, is right?

For several years I have been trying to understand the question, "How many people can the earth support?" and the answers to it. In the process I came to question the question. "How many people can the earth support?" is not a question in the same sense as "How old are you?"; it cannot be answered by a number or even by a range of numbers. The earth's capacity to support people is determined partly by processes that the social and natural sciences have yet to understand, partly by choices that we and our descendants have yet to make.

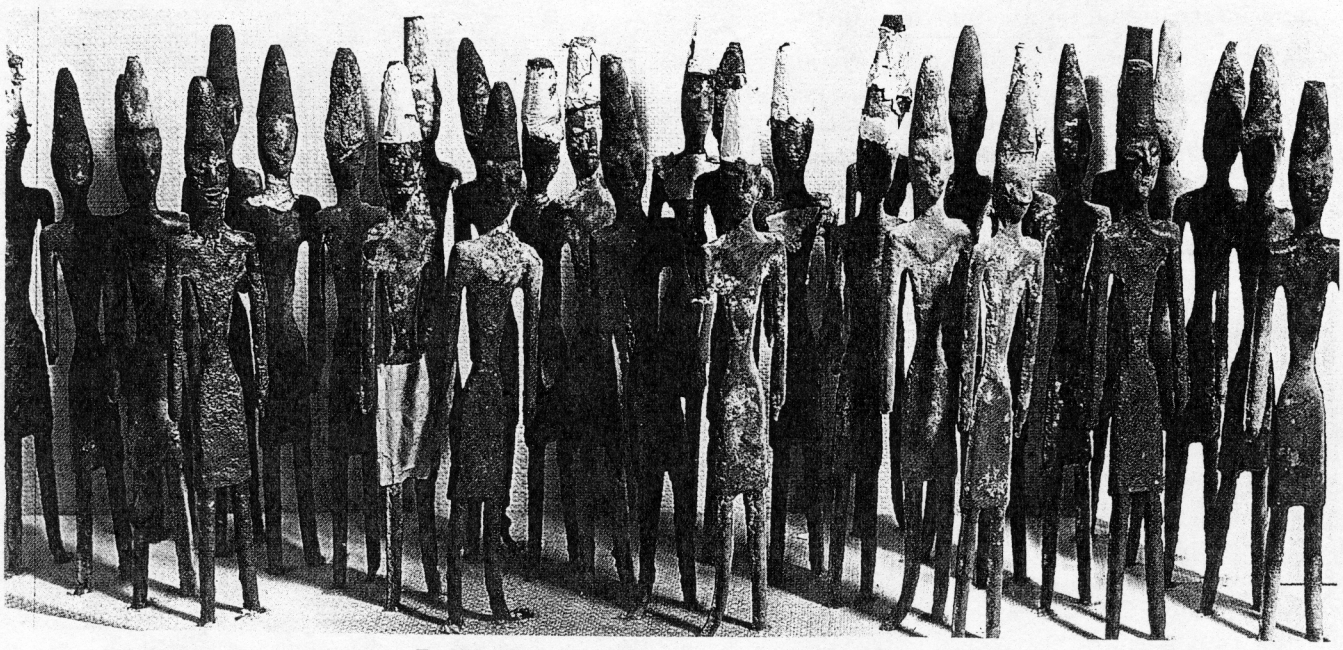
IF POPULATIONS *continue to grow at 1990 rates, the world population will increase to 694 billion by the year 2150.*

IN MOST OF ITS SCIENTIFIC SENSES, *CARRYING capacity* refers to a population of wild animals within a particular ecosystem. One widely used ecology textbook defines it as follows: "Number of individuals in a population that the resources of a habitat can support; the asymptote, or plateau, of the logistic and other sigmoid equations for population growth." Even within ecology, the concept of carrying capacity has important limitations. It applies best under stable conditions and over relatively short spans of time. In the real world, climates and habitats fluctuate and change; animals adapt to their conditions and eventually evolve into new species. With each change, the carrying capacity changes, too.

When applied to human beings, the concept becomes vastly more volatile. I have collected twenty-six definitions of human carrying capacity, all published since 1975. Most of them agree on a few basic points—for instance, that the concept refers to the number of people who can be supported for some period (usually not stated) in some mode of life considered plausible or desirable. Most of the definitions recognize that ecological concepts of carrying capacity must be extended to allow for the role of technology. Most also agree that culturally and individually variable standards of living, including standards of environmental quality, set limits on population size well before the physical requirements for sheer subsistence start to become an issue.

In other respects, however, the definitions vary widely or even contradict one another. How long must a population be sustainable? Does it make sense to speak of local or regional carrying capacity—or do trade and the need for inputs from outside any specified region imply that only a global scale will do? More fundamental, how constraining are constraints? Some definitions deny the existence of any finite carrying capacity altogether, holding that human ingenuity will win out over any natural barriers; others acknowledge that the limits are real but recognize that human choices, now and in the future, will largely decide where those limits fall.

IN MY OPINION, THAT LAST POINT—THE INTERplay of natural constraints and human choices—is the key to making sense of human carrying capacity. The deceptively simple question "How many people can the earth support?" hides a host of thorny issues:



Ex-Voto Statuettes, Byblos, Eighteenth Century B.C.

How many people at what average level of material well-being?

THE HUMAN CARRYING CAPACITY OF THE EARTH WILL OBviously depend on the typical material level at which people choose to live. Material well-being includes food (people choose variety and palatability, beyond the constraints imposed by physiological requirements); fiber (people choose cotton, wool or synthetic fibers for clothing, wood pulp or rag for paper); water (tap water or Perrier or the nearest river or mud hole for drinking, washing, cooking and watering your lawn, if you have one); housing (Auschwitz barracks, two men to a plank, or Thomas Jefferson's Monticello); manufactured goods; waste removal (for human, agricultural and industrial wastes); natural-hazard protection (against floods, storms, volcanoes and earthquakes); health (prevention, cure and care); and the entire range of amenities such as education, travel, social groups, solitude, the arts, religion and communion with nature. Not all of those features are captured well by standard economic measures.

How many people with what distribution of material well-being?

AN ECOLOGIST, AN ECONOMIST AND A STATISTICIAN WENT bow hunting in the woods and spied a deer. The ecologist shot first, and his arrow landed five meters to the left of the deer. The economist shot next, and her arrow landed five meters to the right of the deer. The statistician looked at both arrows, looked at the deer, and jumped up and down shouting: "We got it! We got it!"

Estimates of human carrying capacity rarely take into account the scatter or distribution of material well-being throughout a population. Yet paying attention to average well-being while ignoring the distribution of well-being is like using an average arrow to kill a deer. People who live in extreme poverty may not know or care that the global average is satisfactory, and the press of present needs may keep them from taking a long-term view. For example, thanks to genetic engineering, any country with a few Ph.D.'s in molecular plant biology and a modestly equipped laboratory can insert the genes to create stronger, more disease-resistant, higher-yielding plants. If every region has the scientific and technical resources to improve its own crop plants, the earth can support more people than it can if some regions are too poor to help themselves.

How many people with what technology?

THE COMPLEXITIES OF TECHNOLOGICAL CHOICES OFTEN disappear in heated exchanges between environmental pessimists and technological optimists:

ECOLOGIST: When a natural resource is being consumed faster than it is being replenished or recycled, an asset is being depleted, to the potential harm of future generations.

TECHNOLOGIST: If new knowledge and technology can produce an equivalent or superior alternative, then future generations may turn out to be better off.

TAXPAYER: Which natural resources can be replaced by technology yet to be invented, and which cannot? Will there be enough time to develop new technology and put it to work on the required scale? Could we avoid future problems, pain and suffering by making other choices now about technology or ways of living? [*No answer from ecologist or technologist.*]

The key to the argument is time. As Richard E. Benedick, an officer of the U.S. Department of State who has also served with the World Wildlife Fund, worried:

While it is true that technology has generally been able to come up with solutions to human dilemmas, there is no guarantee that ingenuity will always rise to the task. Policymakers must contend with a nagging thought: what if it does not, or what if it is too late?

How many people with what domestic and international political institutions?

POLITICAL ORGANIZATION AND EFFECTIVENESS AFFECT human carrying capacity. For example, the United Nations Development Program estimated that developing countries could mobilize for development as much as $50 billion a year (an amount comparable to all official development assistance) if they reduced military expenditures, privatized public enterprises, eliminated corruption, made development priorities economically more rational and improved national governance. Conversely, population size, distribution and composition affect political organization and effectiveness.

How will political institutions and civic participation evolve with increasing numbers of people? As numbers increase, what will happen to people's ability to participate effectively in the political system?

What standards of personal liberty will people choose?

How will people bring about political change within existing nations? By elections and referendums, or by revolution, insurrection and civil war? How will people choose to settle differences between nations, for instance, over disputed borders, shared water resources or common fisheries? War consumes human and physical resources. Negotiation consumes patience and often requires compromise. The two options impose different constraints on human carrying capacity.

How many people with what domestic and international economic arrangements?

WHAT LEVELS OF PHYSICAL AND HUMAN CAPITAL ARE assumed? Tractors, lathes, computers, better health and better education all make workers in rich countries far more productive than those in poor countries. Wealthier workers make more wealth and can support more people.

What regional and international trade in finished goods and mobility in productive assets are permitted or encouraged? How will work be organized? The invention of the factory organized production to minimize idleness in the use of labor, tools and machines. What new ways of organizing work should be assumed to estimate the future human carrying capacity?

How many people with what domestic and international demographic arrangements?

ALMOST EVERY ASPECT OF DEMOGRAPHY (BIRTH, DEATH, age structure, migration, marriage, and family structure) is subject to human choices that will influence the earth's human carrying capacity.

A stationary global population will have to choose between a long average length of life and a high birthrate. It must also choose between a single average birthrate for all regions, on the one hand, and a demographic specialization of labor on the other (in which some areas have fertility above their replacement level, whereas other areas have fertility below their replacement level).

Patterns of marriage and household formation will also influence human carrying capacity. For example, the public resources that have to be devoted to the care of the young and the aged depend on the roles played by families.

POLICY MAKERS MUST WONDER:
Will new technology always save the day? What if it arrives too late?

In China national law requires families to care for and support their elderly members; in the United States each elderly person and the state are largely responsible for supporting that elderly person.

How many people in what physical, chemical and biological environments?

WHAT PHYSICAL, CHEMICAL AND BIOLOGICAL ENVIRONments will people choose for themselves and for their children? Much of the heat in the public argument over current environmental problems arises because the consequences of present and projected choices and changes are uncertain. Will global warming cause great problems, or would a global limitation on fossil-fuel consumption cause greater problems? Will toxic or nuclear wastes or ordinary sewage sludge dumped into the deep ocean come back to haunt future generations when deep currents well up in biologically productive offshore zones, or would the long-term effects of disposing of those wastes on land be worse? The choice of particular alternatives could materially affect human carrying capacity.

How many people with what variability or stability?

HOW MANY PEOPLE THE EARTH CAN SUPPORT DEPENDS ON how steadily you want the earth to support that population. If you are willing to let the human population rise and fall, depending on annual crops, decadal weather patterns and long-term shifts in climate, the average population with ups and downs would include the peaks of population size, whereas the guaranteed level would have to be adjusted to the level of the lowest valley. Similar reasoning applies to variability or stability in the level of well-being; the

quality of the physical, chemical and biological environments; and many other dimensions of choice.

How many people with what risk or robustness?

HOW MANY PEOPLE THE EARTH CAN SUPPORT DEPENDS ON how controllable you want the well-being of the population to be. One possible strategy would be to maximize numbers at some given level of well-being, ignoring the risk of natural or human disaster. Another would be to accept a smaller population size in return for increased control over random events. For example, if you settle in a previously uninhabited hazardous zone (such as the flood plain of the Mississippi River or the hurricane-prone coast of the southeastern U.S.), you demand a higher carrying capacity of the hazardous zone, but you must accept a higher risk of catastrophe. When farmers do not give fields a fallow period, they extract a higher carrying capacity along with a higher risk that the soil will lose its fertility (as agronomists at the International Rice Research Institute in the Philippines discovered to their surprise).

How many people for how long?

HUMAN CARRYING CAPACITY DEPENDS STRONGLY ON THE time horizon people choose for planning. The population that the earth can support at a given level of well-being for twenty years may differ substantially from the population that can be supported for 100 or 1,000 years.

The time horizon is crucial in energy analysis. How fast oil stocks are being consumed matters little if one cares only about the next five years. In the long term, technology can change the definition of resources, converting what was useless rock to a valuable resource; hence no one can say whether industrial society is sustainable for 500 years.

IN PRACTICE, RELIGION
does not seem to be decisive in setting average levels of fertility for Roman Catholics.

Some definitions of human carrying capacity refer to the size of a population that can be supported indefinitely. Such definitions are operationally meaningless. There is no way of knowing what human population size can be supported indefinitely (other than zero population, since the sun is expected to burn out in a few billion years, and the human species almost certainly will be extinct long before then). The concept of indefinite sustainability is a phantasm, a diversion from the difficult problems of today and the coming century.

How many people with what fashions, tastes and values?

HOW MANY PEOPLE THE EARTH CAN SUPPORT DEPENDS ON what people want from life. Many choices that appear to be economic depend heavily on individual and cultural values. Should industrial societies use the available supplies of fossil fuels in households for heating and for personal transportation, or outside of households to produce other goods and services? Do people prefer a high average wage and low employment or a low average wage and high employment (if they must choose)?

Should industrial economies seek now to develop renewable energy sources, or should they keep burning fossil fuels and leave the transition to future generations? Should women work outside their homes? Should economic analyses continue to discount future income and costs, or should they strive to even the balance between the people now living and their unborn descendants?

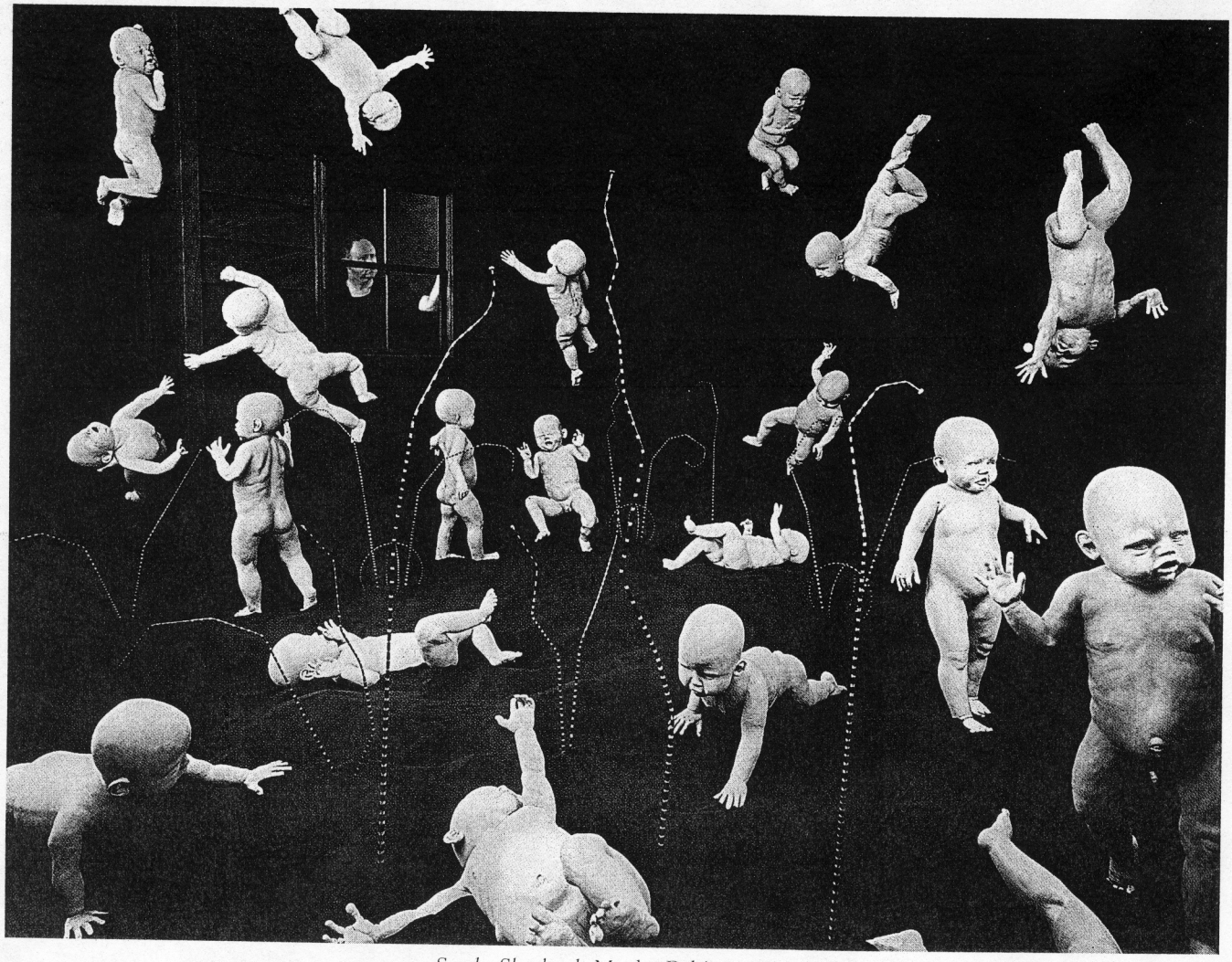
I am frequently asked whether organized religion, particularly Roman Catholicism, is a serious obstacle to the decline of fertility. Certainly in some countries, church policies have hindered couples' access to contraception and have posed obstacles to family planning programs. In practice, however, factors other than religion seem to be decisive in setting average levels of fertility for Roman Catholics. In 1992 two Catholic countries, Spain and Italy, were tied for the second- and third-lowest fertility rates in the world. In largely Catholic Latin America, fertility has been falling rapidly, with modern contraceptive methods playing a major role. In most of the U.S. the fertility of Catholics has gradually converged with that of Protestants, and polls show that nearly four-fifths of Catholics think that couples should make up their own minds about family planning and abortion.

Even within the church hierarchy, Catholicism shelters a diversity of views. On June 15, 1994, the Italian bishops' conference issued a report stating that falling mortality and improved medical care "have made it unthinkable to sustain indefinitely a birthrate that notably exceeds the level of two children per couple." Moreover, by promoting literacy for adults, education for children and the survival of infants in developing countries, the church has helped bring about some of the social preconditions for fertility decline.

On the whole the evidence seems to me to support the view of the ecologist William W. Murdoch of the University of California, Santa Barbara: "Religious beliefs have only small, although sometimes significant, effects on family size. Even these effects tend to disappear with rising levels of well-being and education."

IN SHORT, THE QUESTION "HOW MANY PEOPLE can the earth support?" has no single numerical answer, now or ever. Human choices about the earth's human carrying capacity are constrained by facts of nature and may have unpredictable consequences. As a result, estimates of human carrying capacity cannot aspire to be more than conditional and probable: if future choices are thus-and-so, then the human carrying capacity is likely to be so-and-so. They cannot predict the constraints or possibilities that lie in the future; their true worth may lie in their role as a goad to conscience and a guide to action in the here and now.

The following beautiful quotation from *Principles of Political Economy,* by the English philosopher John Stuart Mill, sketches the kind of shift in values such action might entail. When it was written, in 1848, the world's population was less than one-fifth its present size.



Sandy Skoglund, Maybe Babies, *1983*

There is room in the world, no doubt, and even in old countries, for a great increase of population, supposing the arts of life to go on improving, and capital to increase. But even if innocuous, I confess I see very little reason for desiring it. The density of population necessary to enable mankind to obtain, in the greatest degree, all the advantages both of cooperation and of social intercourse, has, in all the most populous countries, been obtained. A population may be too crowded, though all be amply supplied with food and raiment. It is not good for man to be kept perforce at all times in the presence of his species. A world from which solitude is extirpated, is a very poor ideal. . . . Nor is there much satisfaction in contemplating the world with nothing left to the spontaneous activity of nature; with every rood of land brought into cultivation, which is capable of growing food for human beings; every flowery waste or natural pasture ploughed up, all quadrupeds or birds which are not domesticated for man's use exterminated as his rivals for food, every hedgerow or superfluous tree rooted out, and scarcely a place left where a wild shrub or flower could grow without being eradicated as a weed in the name of improved agriculture. If the earth must lose that great portion of its pleasantness which it owes to things that the unlimited increase of wealth and population would extirpate from it, for the mere purpose of enabling it to support a larger but not a better or a happier population, I sincerely hope, for the sake of posterity, that they will content to be stationary, long before necessity compels them to it.

It is scarcely necessary to remark that a stationary condition of capital and population implies no stationary state of human improvement. There would be as much scope as ever for all kinds of mental culture, and moral and social progress; as much room for improving the Art of Living, and much more likelihood of its being improved, when minds ceased to be engrossed by the art of getting on. Even the industrial arts might be as earnestly and as successfully cultivated, with this sole difference, that instead of serving no purpose but the increase of wealth, industrial improvements would produce their legitimate effect, that of abridging labour. . . . Only when, in addition to just institutions, the increase of mankind shall be under the deliberate guidance of judicious foresight, can the conquests made from the powers of nature by the intellect and energy of scientific discoverers, become the common property of the species, and the means of improving it and elevating the universal lot. ●

JOEL E. COHEN is head of the Laboratory of Populations at Rockefeller University in New York City. *This article is adapted from his forthcoming book,* HOW MANY PEOPLE CAN THE EARTH SUPPORT? *to be published in December by W. W. Norton & Company, and is excerpted with the kind permission of the publisher.* *His paper "Conflict Over World Population: Cairo and Beyond" recently appeared in the New York Academy of Sciences Science Policy Report* SCIENCE, TECHNOLOGY AND NEW GLOBAL REALITIES: ISSUES FOR U.S. FOREIGN POLICY.

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Peer Review

LETTERS FROM READERS

SPRINGING THE POPULATION TRAP

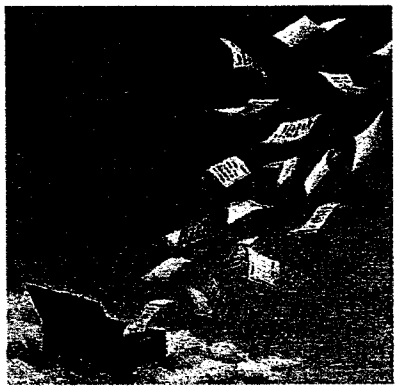
I do not expect fireworks in celebration, but in just two years we will reach the 200th anniversary of Thomas Malthus's *Essay on the Principle of Population*. The bitter contentions among scientists about the vexed population problem have gone on now for more than those 200 years. Pessimists have seen sharp limits to how many people can live on the earth, their argument most often based on limited food supplies. Optimists do not deny that land—and therefore food—is limited, but they think that God or evolution or human ingenuity or some other agency will find a way of solving the problem. Joel E. Cohen's article "How Many People Can the Earth Support?" [November/December] and the book of which it is a foretaste not only present the issues with clarity and fairness to both sides but come closer to their resolution than any work I have previously seen.

The solution is not made easier by the game of musical chairs that has been played. For most of the first 150 years after Malthus's work, economists were the pessimists, with land, labor and capital as their three factors of production. Malthus's contemporary, the English economist David Ricardo, as well as Malthus himself, took for granted that with land fixed there would be declining returns to labor as population grew.

In contrast, with the discovery and acceptance of evolution, Darwin and his interpreter Herbert Spencer were unqualified optimists: evolution had brought humanity to the pinnacle symbolized by the upper-class Victorian gentleman, and it was judged likely to continue to even higher types.

That contentiousness is undiminished in the second half of the twentieth century, but the surprise is that the sides have now interchanged positions. Economists have come to see people as the decisive agent of production and land as unimportant. They argue that the ingenuity of people stimulated by free markets will find a way of overcoming the finite area of the globe and its finite resources. Biologists, on the other side, see a deadly threat in the current destruction of the ecological base of soils and forests on which humanity, along with all other creatures, must necessarily sit. As economists dropped land from most of their models, biologists took it up as the ecological base of humankind, as environment.

The article by Mr. Cohen and the book that will amplify it show how biologists



Fanny Brennan, Love Letters, *1990*

and social scientists can resolve their differences, and from there Mr. Cohen goes on to show how we can escape from the population trap. Mr. Cohen has written, in the words of the biologist Edward O. Wilson, "the definitive work on the global population problem."

In so doing Mr. Cohen has done an enormous service to science and scholarship that could help all disciplines. For when investigators contradict one another in print and in other media, they cast doubt on all branches of science. Congress can dare to cut research budgets, with the disastrous effects such cuts can have on the national future, partly because on a central issue the public sees scientists as engaged in fruitless wrangling.

Mr. Cohen's reasoned resolution of the issues points the way to a reconciliation. After 200 years his work can help us move beyond a sterile debate.

NATHAN KEYFITZ

Harvard University
Cambridge, Massachusetts

¶Joel Cohen's article is perhaps the most inconclusive, question-filled article I have ever read—as well it should be. Mr. Cohen is right to argue that no precise figure for the earth's human carrying capacity can be calculated.

My only misgiving about this fine article concerns the way Mr. Cohen perpetuates the stark distinction between pessimistic "ecologists" and optimistic "technologists." Such a division does a disservice to the growing voice of techno-environmentalism. Once that position is added to the debate, a new set of potential answers—and questions—immediately emerges. Thus whereas Mr. Cohen contends that paper is necessary for "material well-being," I would argue that electronic media could virtually obviate the need for paper (at least for communications) at no cost to our living standards.

A true techno-environmentalist consideration of possible (or optimum) human numbers would factor in the moral necessity of allowing the planet's other inhabitants adequate habitat in which to live and to maintain their evolutionary potential. If Americans were to eat a largely vegetarian diet, wear synthetic fibers, build their houses and furniture from inert materials rather than wood, live in high-density cities connected with ultrafast rail lines, and power the entire system with electricity derived from photovoltaic cells, the country could probably support a larger population than it does at present, at a reasonably high standard of living, and still devote half of its land area to reconstructed natural communities. But as long as we insist on rigidly segregating the environmentalists from the technologists, neither will have the necessary vision to begin the arduous project of devising such a pathway.

MARTIN W. LEWIS

Duke University
Durham, North Carolina

Joel Cohen replies: In the past decade Nathan Keyfitz, a demographer with a uniquely penetrating perspective on his discipline, has urged other demographers as well as economists and ecologists to look over the walls of their disciplinary trenches to the real problems of population. Solving those problems will require everything demography, economics and ecology can offer, and more. My book *How Many People Can the Earth Support?* and the brief excerpt from it in *The Sciences* attempt to respond to his call.

If my article gave the impression that I intended to perpetuate a dichotomy between ecologists and technologists, as Martin Lewis suggests, I am sorry. I intended to describe the extreme positions that can easily be observed today in public statements by some ecologists and some technologists. I agree with Mr. Lewis that a working partnership between ecologists and technologists could make important contributions. I give specific instances of opportunities for partnership in my book—in the use and management of freshwater, for instance. Several recent books (not cited in my own book) elaborate on that essential collaboration: Braden R. Allenby and Deanna J. Richards, *The Greening of Industrial Ecosystems,* National Academy Press, 1994; T. E. Graedel and B. R. Allenby, *Industrial Ecolo-*

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gy, Prentice-Hall, 1995; R. Socolow, C. Andrews, F. Berkhout and V. Thomas, editors, *Industrial Ecology and Global Change*, Cambridge University Press, 1994.

Mr. Lewis emphasizes technology and the environment. Although it is surely necessary to understand and guide the interactions between the environment and the economy (which includes more than technology), that is not enough. Population size, composition and spatial distribution, as well as political and legal institutions and cultural values, will also play crucial roles in determining whether people will live in high-density cities and will give up private automobiles for high-speed rail lines, as Mr. Lewis envisages. I keep in mind the interactions of population, the environment, the economy and culture by visualizing a symmetrical tetrahedron with vertices labeled Population, Environment, Economy and Culture. The symmetry of the tetrahedron implies that population, ecology, the economy or culture could be placed on top without changing the message.