Master

FEATURES

New York Times excerpts (31 August 1974) from the WORLD PLAN OF ACTION adopted by the U.N. World Population Conference.

Five articles from Scientific American, September 1974 on various aspects of over-population.

Despite some adverse publicity, progress was achieved at the first World Population Conference sponsored by the U.N. in Bucharest in August 1974 in which 1300 delegates from 135 nations sat down and discussed one of today's most controversial subjects. Debates were heated, but some of the areas of misunderstanding they exposed are repairable and the conference provided for a continuing review mechanism in the U.N. to monitor population trends.

The draft plan identified runaway population growth as a threat to worldwide development and recommended that population limitation be made a major component of all national development policies. The role of economic and social development as a means of coping with population problems was emphasized at the insistence of Third World nations but even with the obvious resentment and trepidation of the have nots as to the motives of the haves, worthwhile recommendations for social and economic development came out of the final plan including: expanding educational opportunities; discouraging early marriages; eliminating child labor; upgrading the position of women; establishing social security and old-age benefits, etc. Population experts state that such measures have historically had the effect of lowering birth rates. The reasons are spelled out in the attached articles which are filled with solid background material that can be turned into articles for mass-circulation newspapers and magazines.

Reservations among developing nations that family planning programs would deprive them of the larger population they are counting on to swell their industrial labor force are covered in two articles, "The Human Population" and "The History of the Human Population", which describe the decades-long lag between lower fertility and a lower population growth rate. Hence, Third World countries can be assured that they will not lose out on the benefits of population growth if they adopt family planning programs now.

8 Oct 74

Excerpts From Report of Population Talks

BUCHAREST, Aug. 30— *Following are excerpts from the Plan of Action adopted today by the United Nations World Population Conference:*

Special to The New York Times

General Objectives

To advance understanding of population at national, subnational, regional and global levels, recognizing the diversity of the problems involved.

To advance national and international understanding of the interrelatedness of demographic and socio-economic factors in development, of the nature and scope of the contribution of demographic factors to the attainment of goals of advancing human welfare, on the one hand, and the impact of broader social, economic and cultural factors on demographic behaviour on the other.

To promote socio-economic measures and programs whose aim is to affect, inter alia, population growth, morbidity and mortality, reproduction and family formation, population distribution and internal migration, international migration, and consequently demographic structures.

To advance national and international understanding of the complex relations among the problems of population, resources, environment and development, and to promote a unified analytical approach to the study of this interrelationship and to relevant policies.

Stress on Status of Women

To promote the status of women and expansion of their role, the full participation of women in the formulation and implementation of socio-economic policy, including population policies, and the creation of awareness among all women of their current and potential roles in national life.

To recommend guidelines for population policies consistent with national values and goals and with internationally recognized principles.

To promote the development and implementation of population policies where necessary, including improvement in the communication of the purposes and goals of these policies to the public and the promotion of popular participation in their formulation and implementation.

To encourage the development and good management of appropriate education, training, research, information and family health services, as well as statistics in support of the above principles and objectives.

Recommendations for Action

Countries which consider that their present or expected rates of population growth hamper their goals of promoting human welfare are invited, if they have not yet done so, to consider adopting population policies, within the framework of socio-economic development, which are consistent with basic human rights and national goals and values.

Countries which aim at achieving moderate or low population growth should try to achieve it through a low level of birth and death rates.

Recognizing that per capita use of world resources is much higher in the more developed than in the developing countries, the developed countries are urged to adopt appropriate policies in population, consumption and investment, bearing in mind the need for fundamental improvement in international equity.

Development Goals Listed

It is agreed that the following development goals generally have an effect to moderate fertility levels:

A. The reduction of infant and child mortality, particularly by means of improved nutrition, sanitation, maternal and child health care, and maternal education.

B. The full integration of women into the development process, particularly by means of their greater participation in educational, social, economic and political opportunities, and especially by means of the removal of obstacles to their employment in the nonagricultural sector wherever possible. In this context, national law as well as relevant international recommendations should be reviewed in order to eliminate discrimination in, and remove obstacles to, the education, training, employment and career advancement opportunities for women.

C. The promotion of social justice, social mobility and social development, particularly by means of a wide participation of the population in development and a more equitable distribution of income, land, social services and amenities.

D. The promotion of wide educational opportunities for the young of both sexes and the extension of public forms of preschool education for the rising generation.

E. The elimination of child labor and child abuse and the establishment of social-security and old-age benefits.

The establishment of an appropriate lower limit for age at marriage.

Projections of Declines

Projections of future declines in rates of population growth, and those concerning increased expectation of life, are consistent with declines in the birth rate of the developing countries as a whole from the present level of 38 per thousand to 30 per thousand by 1985. In these projections, birth rates in the developed countries remain in the region of 15 per thousand.

To achieve by 1985 these levels of fertility would require substantial national efforts by those countries concerned, in the field of socio-economic development and population policies, supported, upon request, by adequate international assistance. Such efforts would also be required to achieve the increase in expectation of life.

Countries which consider their birth rates detrimental to their national purposes are invited to consider setting quantitative goals and implementing policies that may lead to the attainment of such goals by 1985. Nothing herein should interfere with the sovereignty of any government to adopt such quantitative goals.

It is recommended that:

A. Education for girls as well as boys should be extended and diversified to enable them to contribute more effectively in rural and urban sectors as well as in the management of food and other household functions.

B. Women should be actively involved both as individuals and through political and nongovernmental organizations, at every stage and every level in the planning and implementation of development programs, including population policies.

C. The economic contribution of women in household and farming should be recognized in national economies.

D. Governments should make a sustained effort to insure that legislation regarding the status of women complies with the principles spelled out in the Declaration on the Elimination of discrimination Against Women and other United Nations declarations, conventions and international instruments to reduce the gap between law and practice through effective implementation, and to inform women at all socio-economic levels of their legal rights and responsibilities.

Long Term Assay Uureg

In Planning development, and particularly in planning the location of industry and business and the distribution of social services and amenities, government should take into account not only short-term economic returns of alternative patterns but also the social and environmental costs and benefits involved as well as equity and social justice in the distribution of the benefits.

It is imperative that all countries, and within them all social sectors, should adapt themselves to more rational utilization of natural resources, without excess, so that some are not deprived of what others waste. In order to increase the production and distribution of food for the growing world population, it is recommended that governments give high priority to improving methods of food production, the investigation and development of new sources of food and more effective utilization of existing sources. International cooperation is recommended with the aim of insuring the provision of fertilizers and energy and a timely supply of foodstuffs to all countries.

It is strongly recommended that national policies be formulated and implemented without violating, and with due promotion of, universally accepted standards of human rights.

International cooperation, based on the peaceful coexistence of states having different social systems, should play a supportive role in achieving the goals of the Plan of Action. This supportive role could take the form of direct assistance, technical or financial, in response to national and regional requests and be additional to economic development assistance.

It is recommended that monitoring of population trends and policies discussed in this Plan of Action should be undertaken continuously as a specialized activity of the United Nations and reviewed biennially by the appropriate bodies of the United Nations system, beginning in 1977. A comprehensive and thorough review and appraisal of progress made toward achieving the goals and recommendations of this Plan of Action should be undertaken [illegible] by the United Nations system.

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The Human Population

The articles presented in this issue point out, among other things, that rapid population growth cannot last long. The question is: Will population level off because of high death rates or low birth rates?

by Ronald Freedman and Bernard Berelson

The rate of growth that currently characterizes the human population as a whole is a temporary deviation from the annual growth rates that prevailed during most of man's history and must prevail again in the future. Today's situation is unique in mankind's experience: the highest growth rate in human history (about 2 percent per year) from the highest base in absolute numbers (nearly four billion). The world is currently adding nearly 80 million people per year, about as many as the population of the eighth-largest country (Bangladesh).

Over the millenniums until very recent times the human population increased at a very low rate. From the time of the agricultural and urban revolution about 5,000 years ago the population increase probably never reached as much as .1 percent a year for any long period until the late 17th century. As Ansley J. Coale shows elsewhere in this issue [see "The History of the Human Population," page 40], the acceleration of world population growth was particularly pronounced in countries that are among the most highly developed today: the European countries and the lands Europeans settled overseas. That growth was the product of the decline in their death rates, prolonged over three centuries and most marked from about 1800 on, and the lag in the parallel decline in their birth rates. Now the population is engaged in what can truly be called a vital revolution. We happen to live in the crucial transitional generations. Earlier the high fertility of mankind was balanced by high mortality. Currently, however, death rates have been falling almost everywhere. The birth rate has also been falling in many nations and communities, but this trend has come along later and more slowly. The population has therefore been increasing, and up to now at an increasing rate. In the 1970's the rate of increase has slightly exceeded 2 percent per year. That means a doubling time of less than 35 years, and the number currently being doubled is a very large one. Projection of such growth for very long into the future produces a world population larger than the most optimistic estimates of the planet's carrying capacity. In the long run near-zero growth will have to be restored—either by lower birth rates or by higher death rates.

Moreover, the world is demographically divided. The developed countries are now close to replacement levels of reproduction (although there is no certainty that they will remain there). The underdeveloped countries are growing very fast: mortality is falling more or less rapidly, but fertility is changing very little, except in a few small countries. The differing age structures of the two kinds of population contribute their own problems.

The possibility that growth may be halted and the population stabilized by the control of fertility is illustrated by the recent demographic history of the developed countries: some 30 nations, as classified by the appropriate agencies of the United Nations, that share in the material abundance of industrialization. Decline in the death rates of these countries has given their populations life expectancies that approach or exceed 70 years. The age structure of these populations, trending toward roughly equal numbers in every age cohort up to the sixth decade [*see top illustration on pages 38 and 39*], constitutes a biological novelty not seen before in human populations. Fertility rates in many developed countries have declined close enough to their

HUMAN POPULATION OF SOME 5,000 YEARS AGO depicted itself in the rock paintings on the opposite page. The paintings are in the Tassili, a remote mountainous region of the Sahara on the southern border of Algeria. The running human figures carrying bows are hunters, but these people were probably pastoral nomads. The large animal in the center is a bull. At that time the Sahara was not as dry as it is today, and it may have been the scene of the human migrations that attended the introduction of animal husbandry and agriculture. The photograph was made by L. L. Cavalli-Sforza of Stanford University, the author of one of the articles in this issue ("The Genetics of Human Populations," page 80).

death rates to produce near-zero rates of growth, given a little time. Confidence about the ultimate stabilization of these populations must be qualified, however, by recollection of the upsurge in their birth rates during the 1940's and 1950's (familiar to U.S. citizens as the "baby boom" of the years that followed World War II) that temporarily reversed the trend of the preceding century. These vital trends originally put in their appearance with the onset of the scientific-industrial revolution and the popularization of material well-being that has made the countries of the European peoples the developed countries of today. The same trends are observed in the Japanese population from the time of the Meiji restoration in 1868, which launched that country's industrial revolution.

As early as the 1930's what has become known as the demographic transition culminated, in many of those countries, in the convergence of birth and death rates that brought their growth down close to zero. Since there is no accepted explanation for the subsequent surge and decline of their fertility rates, no one can say with assurance that something similar will not happen again. In any case the demographic future of this portion of the human population is now a function of movement in its birth rates. Further decline in mortality (even to zero!) would have little effect on growth; almost everyone in the developed world now lives past the childbearing years, and saving the lives of older people does not affect the growth rate of a population to any degree. With modern contraceptive technology widely available and in use in most developed countries, their birth rates may be said to be under voluntary control. It can be anticipated, as Charles F. Westoff observes [see "The Populations of the Developed Countries," page 108], that human fertility in these novel circumstances will oscillate in response to cultural and economic pulls and pressures, not yet securely understood. The conjugal family of industrial civilization [see "The Family in Developed Countries," by Norman B. Ryder, page 122] is typically a small family. And the true liberation of women from the commitment of their lives to childbearing [see "The Changing Status of Women in Developed Countries," by Judith Blake, page 136] sets another kind of inertia against return to high levels of fertility.

Even so, some of these populations still retain considerable potential for growth. Higher birth rates in the recent past mean large proportions of couples who must live through their reproductive years before zero growth will be achieved. Thus even if the country's fertility persists at a replacement level, the U.S. will not reach zero growth for 50 or 60 years, at which time its population will be 40 percent larger.

The principal impetus to world population growth comes today from the underdeveloped countries where nearly three-fourths of mankind dwell. Death rates in those countries have been falling over the past 25 years toward the low levels of the developed countries. Birth rates, however, remain twice as high as they are in the developed countries. The result is a population increase averaging 2.5 percent and in many countries exceeding 3 percent.

The populations of such countries are now growing faster than those of the developed countries grew during the phase of rapid population growth of the European peoples [see "The Populations of the Underdeveloped Countries," by Paul Demeny, page 148]. Mortality rates in such countries are converging toward those of the developed countries, although there is still some way to go, particularly when age structures are taken into account. (The crude death rates of the underdeveloped countries run about 14 per 1,000 population, as against about nine per 1,000 in the developed countries.) In some countries further decline in mortality may come slowly without further improvement in nutrition, living standards and public health services. The large gaps between the underdeveloped and the developed countries remain in fertility, represented by an overall crude birth rate of 39 per 1,000 population compared with 17 per 1,000. Some large countries such as Nigeria, Bangladesh and Pakistan have crude birth rates that are three times higher than those of the U.S.

Accordingly it is almost inevitable that the world's population will grow to between 6.5 billion and 8.5 billion in the next 75 years, with nearly all the growth in the underdeveloped countries. As Tomas Frejka of the Population Council has shown, employing a computer model of the world population that incorporates data on age structure, the population would grow to 6.3 billion even if reproduction rates in all countries could be brought down to replacement levels as early as 1980 [see "The Prospects for a Stationary World Population," by Tomas Frejka; SCIENTIFIC AMERICAN, March, 1973]. Arrival at the replacement rate by the end of the century, a more plausible but by no means certain event, would yield a world population of 8.2 billion in 2050. More than 90 percent of the additional four-plus billion would be in the underdeveloped countries. The world would know an India of 1.4 billion population, a Brazil of 266 million, a Bangladesh of 240 million, a Nigeria of 198 million. China is the big unknown in world statistics; in spite of reports of a decline in the country's fertility rate, a population of more than a billion is probable in the next decades.

Thus short of a catastrophic rise in death rates a population increase of major dimensions is in store. Stabilization of the world population may not occur this side of the 10-to-15-billion range, and eight billion seems to be a minimum.

Whatever mankind can do to moderate such trends, it must clearly accommodate to growth. Over the next few decades roughly everything must be doubled just in order to stay even. Roger Revelle [see "Food and Population," page 160] considers that the projected demand—amplified as it must be by the appetites of the developed countries and by the development of the underdeveloped countries—still does not exceed the earth's resources.

Concurrent with such profound change in the facts of life and death and in the structure of populations, the living generations have been experiencing equally revolutionary changes in the family, the community and the state, in technology and the use of resources, in economic relationships and in man's impact on the environment. These changes in the condition of man can be signalized by the observation that the human population is in migration from the agricultural village to the industrial and commercial city [see "The Migrations of Human Populations," by Kingsley Davis, page 92]. Everywhere cities are growing faster than countries. In the developed countries the majority of the inhabitants are already resettled into great networks of metropolitan centers with dependent hinterlands. Although most people in the underdeveloped countries still live in villages, their cities are growing too, in spite of grossly inadequate facilities and relatively little opportunity for employment. Such high rates of population growth prevail in rural areas that this migration still does not diminish the rural population or even slow its growth by much.

Most of the world's people now live in countries with programs or policies to change fertility levels and growth rates, but efforts either to increase or to [illegible] appear to have had

mixed results. If population growth is [illegible] be halted and stabilized by fertility control, then the faster fertility is reduced, the smaller the eventually stationary population will be. The governments of most underdeveloped countries sponsor family-planning programs, usually but not always with the explicit goal of reducing the number of births. In some smaller countries, notably Taiwan and South Korea, birth rates have fallen to a substantial degree because of birth control practiced by couples served by such programs. Whether this would have happened without the programs is still a debated question and one technically difficult to resolve. These same countries have also made substantial progress in other ways toward the fulfillment of aspirations for economic development and "modernization."

Government policies with respect to fertility in developed countries, whether implicit in welfare programs or explicit in the promotion of large families, tend to be pronatalist. There is no evidence, however, that such policies have been notably successful in deflecting the downward trend in birth rates in those countries more than temporarily. It may be expected that when the underdeveloped countries have changed all those characteristics that distinguish the traditional society from the modern one, they too will be developed, and one result will be the reduction of their fertility.

As the other contributors to this issue give evidence, there is substantial agreement about the demographic trends and conditions that set the terms of public policy. The making of policy, however, involves ideology as well as the demographic and social facts. It may seem strange that some people question the validity and definition of "the population problem" at this late date, but there are at least two recent developments of considerable importance. The first is a growing scientific sophistication about the consequences of population growth, as the simpler answers of 10 to 15 years ago give way to more qualified and more complex ones. The second is a broadening of the definition of the problem to include not only economics but also the terrestrial environment, to regard population growth not only as a burden on the development of underdeveloped countries but also as a multiplier of the stresses on the resources and the environment of developed countries.

On the economic side the bible of the early 1960's was Ansley Coale and Edgar M. Hoover's *Population Growth and Economic Development in Low-Income Countries*, an estimate of how much high growth rates would retard development. In one underdeveloped country after another rapid population growth appears to increase the difficulty of working with limited human and material resources to solve the problems of food supply, of urban and rural unemployment, of providing minimal social services. The predominant view still is that rapid population growth is such a serious hindrance to development that the reduction of fertility rates will greatly enhance the possibility of social and economic progress. There is, however, another view. In the early 1970's a UN symposium preparatory to the 1974 World Population Conference, with experts from around the world in attendance, concluded that "a preoccupation with population should not divert attention from critical issues in the world development process.... Population growth is not always an obstacle to development [although] very high rates of population growth are usually an obstacle to development."

Today such analysis is questioned with regard to the handling of discount rates and the extent to which savings by low-income individuals contribute to capital investment. Moreover, the advantages of population growth are asserted: stimuli to harder work and agricultural innovation, and larger markets to foster the substitution of imports. Such questions have led some to the fundamental position that it is not population growth that matters but the proper organization of society, the redistribution of income and the rectification of social injustice. Does population growth seriously threaten economic development or is it only a marginal issue? Today qualified experts can be found on both sides of the debate.

In the recent concern with the environmental aspect of population the tables are turned: in one scenario the problem is not the problem of countries such as India but the problem of countries such as the U.S.; the solution calls not for fewer babies there but for less consumption here. The debate has swung between extremes, with one position being stigmatized as doomsaying and the other as technological optimism.

One can distinguish at least three general positions on the population problem. There is population as crisis, so grave that catastrophe is near unless drastic steps are taken to stop world population [illegible] multiplier and intensifier of other social [illegible] something," but a substantial something; an example is the 1972 report of the U.S. Commission on Population Growth and the American Future. Then there is population as a nonproblem (or even a false problem with imperialist overtones), the real problem being development or how to bring about a socialist organization of society or redistribute income or improve the status of women or rectify social injustice or promote technological change, with the population problem being automatically taken care of as a by-product. In short, the very nature of the population problem—what the real consequences of population growth are and what growth really means for human life—is under closer scrutiny and disputation today than it was a decade ago.

It was inevitable that the increased interest in population during the 1960's would move the subject into the political arena. Indeed, that was demanded by the emergence of government population policies. As a result population issues are now caught up in broader and deeper political tensions, both domestic and international: tensions concerning natural resources, food, energy, medical care, neocolonialism, the terms of international trade, the provision of assistance for development and the relative merits of socialist and nonsocialist forms of government.

Any strong international trend, and population-related actions were such a trend in the 1960's, is likely to generate a countertrend. Now, for better or worse, there is a kind of political backlash at work in many parts of the world with which workers in the field of population problems must contend in addition to the problems themselves. Any effort to limit this sensitive topic to scholarly and professional discussion was doomed to failure; after all, if a policy is to be recommended by a government, it by definition becomes a political matter.

A key controversy centers on the strategy for reducing fertility rates in the underdeveloped countries. In the public forum such consideration has tended to focus on the alternatives of economic development and family planning. It is an unrewarding polarization. Political leaders are pushed by events to treat population and development policies as being integrally related rather than as alternatives.

Development, which requires extensive social change, impinges at every point on factors that sustain high fertility in the underdeveloped countries. Poverty so extreme, widespread and persistent

holds people in despairing resistance to change. The high rate of infant mortality makes the next infant a desirable hedge against high mortality rates. In many countries the preference for sons presses fertility still further against that other lottery of sex determination. The economic value of children in these circumstances contrasts with the dependency of youth in the developed countries: they help to make the family's living; they are the support of their parents in illness and old age, and their value is affirmed in social and religious life. Women are held in inferior status by the dedication of their life role to that of mother, wife and worker in the family enterprise. Illiteracy reinforces social isolation and traditional behavior; lack of education confines the range of choice and the time horizon of decisions about life. Village life limits the exchange of goods, ideas and people; it also limits the complexity of technology and the division of labor.

All aspects of this pattern of underdevelopment do not prevail everywhere, and various countries have arrived at different states of change in these characteristics. Many countries differ in important ways from their European precursors at a similar stage in the transformation, exhibiting a much more rapid decline in mortality, a greater access to advanced technology and an aspiration to quickly reach demonstrated goals that were attained only slowly by the first arrivals. These differences may facilitate reduction in fertility, along with development in general, in some countries. Modernization is proving to be slow and difficult, however, in many countries; if decline in fertility must wait out the process of social transformation, it will be some time in coming. In the last article in this issue Gunnar Myrdal reminds us that the task of technology transfer requires action by the developed as well as the underdeveloped countries [see "The Transfer of Technology to Underdeveloped Countries," page 172].

Fertility control may not require the total transformation of the old order in the underdeveloped countries. Recent research on the demographic transition in Europe finds that decline in fertility did not "automatically" follow on attainment of this or that bench mark in urbanization, industrialization, literacy or decline in mortality. In our time major declines in mortality have occurred with little social or economic development. Educational levels have been raised rapidly in Sri Lanka and in the state of Kerala in India; this has been attended by some decline in fertility, although there has been little economic change.

Beyond general development, which is pursued on its own nondemographic grounds, family-planning programs have been organized in many countries as direct action on the problem of population growth. Such effort has found its own justification, furthermore, on humanitarian and medical grounds, even though its success in fertility control is debated. The effort also commends itself because it is relatively cheap; it spreads the word and so contributes to modernization and it provides access to contraceptive services as progress in development increases motivation. Here again the developed countries have a role to play. As Sheldon J. Segal shows [see "The Physiology of Human Reproduction," page 52], the existing technology of contraception may have serious limitations in the physical circumstances of the traditional village and in the slums of the new cities of the poor; the "ideal contraceptive" is still awaited in the underdeveloped countries as it is in the developed ones and may have a more decisive historic role in the former, allowing fertility control in less favorable physical circumstances and at lower levels of motivation.

Against this background what can governments do to change fertility rates? It can be said there are five courses of action: persuade, manipulate services, change incentives, transform social institutions, coerce. Family-planning programs provide services and persuasion, and some countries restrict access to modern means of fertility control; development, of course, changes social institutions. In Singapore some incentives are being tried: no paid maternity leave beyond two children, and similar scaling of obstetrical delivery fees and income-tax deductions; Taiwan offers a positive incentive in the form of educational bonds for parents who stop at three children. If community pressure backed up by a one-party political apparatus counts as "coercion," then China may be the first country to employ all five ways of fertility control specified here; reports from some cities and communes indicate that China's fertility rate is indeed falling. India, in 1952, was the first country in the world to proclaim a population policy designed to lower birth rates through a family-planning program. It has conducted a vigorous campaign of persuasion under the symbol of the "Red Triangle"; it has tried to provide services on a massive basis, with spotty success; it has used monetary incentives, for example, to promote vasectomy; it has made some progress in the development and the transformation of social institutions. The government of Bangladesh, an even harder-pressed country, has reckoned openly with the possibility of such coercive measures as limitation on ration cards and compulsory sterilization for parents who have had more than two children.

Finally, serious issues present themselves under the heading of the control of human mobility. Today both internal and international migration is predominantly in the rural-to-urban direction: from the countryside to the city, from the farms of one nation to the factories of another. In most places this trend presents causes for concern: urban congestion, unemployment, environmental deterioration, problems of housing and sanitation and transportation, lack of social services, political unrest and difficulties of acculturation.

International migrations are usually controllable: the valve of immigration can be opened or closed. A few countries want more immigrants (Israel and Australia are examples), but even they want only a certain kind. The industrial countries of continental Europe want more laborers from the Mediterranean countries but only on a temporary basis: the unemployed are exportable each way. In some tragic situations minority groups are forced out in order to make the remaining population more homogeneous. In the U.S. the Commission on Population Growth and the American Future urged that the substantial illegal immigration be stopped.

Internal migration to the cities is more difficult to affect. Among the many examples of what has been tried to limit the growth of large urban centers are regional development (Greece and Finland), decentralization of government activities (the Netherlands), relocation of the capital (Brazil and Tanzania), support of new towns (Japan and Britain), damping of wage differentials between urban and rural areas (Zambia), reorientation of education toward agricultural interests (Indonesia and Tanzania), subsidies for industrial location (France, Sweden and Togo), rural land reclamation (Kenya) and even a "citizenship tax" on living in the city (Seoul in South Korea).

The effect of such efforts, although difficult to measure, has not been striking, and the further modernization of agriculture will intensify the pressures. The cities can only be expected to grow even more, with all the problems that implies. Again there is the (reported) counterexample of China, where as a

matter of national policy migration to the cities is stringently controlled and many people are actually exported for various periods from the cities back to the land.

If the task is to reduce population growth in the world as a whole, and hence in most individual countries, at a rate substantially higher than the one that would otherwise obtain, the prospect is uncertain. Reasons for pessimism are not hard to find. First, high fertility itself is greatly resistant to change. It has been ratified by the experience of centuries, and for most people in the world it is institutionally interwoven with the entire cultural fabric. Beyond that the demographic momentum built into the age structure of populations is profound and long-lasting. If one were looking for a promising arena in which to demonstrate the possibilities of social engineering, one would not choose population.

Second, the means of intervention may not be available. Coercion is not generally acceptable. The modernizing of social institutions is a goal almost everywhere, but progress is disappointing, and in any case it is hardly achievable in the immediate future. Family planning can claim some limited successes, but there is no proved formula for the mass adoption of birth control in an underdeveloped country. Hence intervention comes up against real limits of social and government policy.

Third, population issues are themselves changing. On the one hand they have become politicized, with all that implies in the way of disputation, compromise and absorption into political issues. On the other hand, the technical bases of population issues have shifted in recent years; as we come to know more we seem to end up knowing less, at least insofar as effective direct action is concerned. The population problem is more problematic now. The threshold factors required for the reduction of fertility are more in dispute; the value of family planning is called into question with alternatives being advanced that are hard to attain quickly, such as social revolution or the redistribution of income or the correction of social injustice.

Nevertheless, the effort continues. The present is a period of taking stock and reformulating programs. Growing recognition of the difficulty of population problems, together with the great pressures exerted in many countries by food shortages and a wide range of unmet demands for a better life, are forcing many governments to reconsider their entire strategy for development, in part to accommodate population growth and to control it. After all, policy to limit fertility is a very recent effort to deal with a very difficult problem. Successes in some countries and the possibility that there has been a major advance in China provide some practical encouragement.

Most countries are committed to consideration if not to action. Indeed, 1974 is World Population Year, by proclamation of the UN. Representatives of most of the world's governments have just met under UN auspices to discuss population problems and to consider a "World Plan of Action." Such a meeting would have been unthinkable as recently as 15 years ago, when even such matters as family-planning programs were defined as being outside the area of legitimate government action. Population issues, the preserve of a small group of specialized scholars a few decades ago, are now discussed everywhere and are being acted on in countries involving most of the world's people.

Not all population measures are successful. How could they be? Neither are measures on other great social problems. As has been said, some problems do not have solutions, only consequences. There is now, however, an unprecedentedly widespread recognition that the world is going to have to accommodate several billion more people in the coming decades, that the curve of growth takes a long time to level off and that the earlier it begins to level off, the better.

The History of the Human Population

Until some 200 years ago the size of the human population remained fairly stable because high birth rates were balanced by high death rates. The great demographic transition came when death rates fell

by Ansley J. Coale

In designating 1974 World Population Year the United Nations has given expression to worldwide interest in the rapid rate of population increase and to apprehension about the consequences of continued rapid growth. Much less attention is given to the growth of the population in the past, to the process by which a few thousand wanderers a million years ago became billions of residents of cities, towns and villages today. An understanding of this process is essential if one would evaluate the present circumstances and future prospects of the human population.

Any numerical description of the development of the human population cannot avoid conjecture, simply because there has never been a census of all the people in the world. Even today there are national populations that have not been enumerated, and where censuses have been taken they are not always reliable. Recent censuses of the U.S., for example, have undercounted the population by between 2 and 3 percent; some other censuses, such as the one taken in Nigeria in 1963, are evidently gross overcounts. Moreover, in many instances the extent of the error cannot be estimated with any precision.

If the size of the population today is imperfectly known, that of the past is even more uncertain. The first series of censuses taken at regular intervals of no more than 10 years was begun by Sweden in 1750; the U.S. has made decennial enumerations since 1790, as have France and England since 1800. The census became common in the more developed countries only in the 19th century, and it has spread slowly to other parts of the world. India's population has been enumerated at decennial intervals since 1871, and a number of Latin American populations have been counted, mostly at irregular intervals, since late in the 19th century. The first comprehensive census of Russia was conducted in 1897, and only four more have been made since then. The population of most of tropical Africa remained uncounted until after World War II. A conspicuous source of uncertainty in the population of the world today is the poorly known size of the population of China, where the most recent enumeration was made in 1953 and was of untested accuracy.

As one considers earlier periods the margin of error increases. The earliest date for which the global population can be calculated with an uncertainty of only, say, 20 percent is the middle of the 18th century. The next-earliest time for which useful data are available is the beginning of the Christian era, when Rome collected information bearing on the number of people in various parts of the empire. At about the same time imperial records provide some data on the population of China, and historians have made a tenuous estimate of the population of India in that period. By employing this information and by making a crude allowance for the number of people in other regions one can estimate the population of the world at the time of Augustus within a factor of two.

For still earlier periods the population must be estimated indirectly from calculations of the number of people who could subsist under the social and technological institutions presumed to prevail at the time. Anthropologists and historians have estimated, for example, that before the introduction of agriculture the world could have supported a hunting-and-gathering culture of between five and 10 million people.

From guesses such as these for the earlier periods and from somewhat more reliable data for more recent times a general outline of the growth of the human population can be constructed [*see illustrations on next page*]. Perhaps the most uncertain figure of all in these calculations is the size of the initial population when man first appeared about a million years ago. As the human species gradually became distinct from its hominid predecessors there was presumably an original gene pool of some thousands or hundreds of thousands of individuals. The next date at which the population

RUBBING OF A GRAVESTONE records the death of a mother and her child in 18th-century Massachusetts. The inscription reads (with emended punctuation and orthography): "In Memory of Mrs. Naomi, Wife of Mr. Ritchard. Woolworth, who died August 22d. 1760, aged 39 Years; also Joseph, their Son, died the Same Day aged 6 days." It is probable that both mother and son died as a result of some crisis attendant on childbirth, in the case of the mother perhaps from puerperal fever. Such deaths were very common throughout most of man's history; the high death rate they contributed to demanded that the birth rate also be high merely to sustain the population. A decline in the death rate, which had an important effect on the survival of infants and children, began in most parts of Europe and America in the decades following the events recorded on this gravestone. The figures at the top of the stone are a scythe and an hourglass, traditional symbols of mortality; a crowing cock, which probably represents an admonition to vigilance, and an object whose identity is uncertain but that may be a candle with snuffer, another commonplace figure in the imagery of death. The stone is at Longmeadow, Mass., and has been attributed to Aaron Bliss. The rubbing is reproduced from *Early New England Gravestone Rubbings*, by Edmund Vincent Gillon, Jr., published by Dover Publications, Inc. Surveys of gravestone [illegible]

can be estimated is at the initiation of agriculture and the domestication of animals, which is generally believed to have begun about 8000 B.C. The median of several estimates of the ultimate size of the hunting-and-gathering cultures that preceded the introduction of agriculture is eight million. Thus whatever the size of the initial human population, the rate of growth during man's first 990,000 years (about 99 percent of his history) was exceedingly small. Even if one assumed that in the beginning the population was two—Adam and Eve—the annual rate of increase during this first long interval was only about 15 additional persons per million of population.

After the establishment of agriculture the growth of the population accelerated somewhat. The eight million of 8000 B.C. became by A.D. 1 about 300 million (the midpoint of a range of informed guesses of from 200 million to 400 million). This increase represents an annual growth rate of 360 per million, or, as it is usually expressed, .36 per 1,000.

From A.D. 1 to 1750 the population increased by about 500 million to some 800 million (the median of a range estimated by John D. Durand of the University of Pennsylvania). It was at this time that the extraordinary modern acceleration of population growth began. The average annual growth rate from A.D. 1 to 1750 was .56 per 1,000; from 1750 to 1800 it was 4.4 per 1,000, bringing the population at the end of this 50-year interval to about a billion. By 1850 there were 1.3 billion people in the world, and by 1900 there were 1.7 billion, yielding growth rates in the respective 50-year intervals of 5.2 and 5.4 per 1,000. (These totals too are based on estimates made by Durand.)

By 1950, according to the UN, the world population was 2.5 billion, indicating an annual growth rate during the first half of the 20th century of 7.9 per 1,000. From 1950 to 1974 the growth rate more than doubled, to 17.1 per 1,000, producing the present world population of 3.9 billion. The median value of several projections made by the UN in 1973 indicates that by 2000 the population will be 6.4 billion, an increase that implies an annual growth rate during the next 25 years of 19 per 1,000.

It is evident even from this brief description that the history of the population can be readily divided into two periods: a very long era of slow growth and a very brief period of rapid growth. An understanding of the development of the population during these two phases can be derived from a few simple mathematical relations involving the absolute size of the population, the growth rate and the factors that determine the growth rate.

Persistent growth at any proportionate rate produces ever increasing increments of growth, and the total, even at a relatively modest rate of increase, surpasses any designated finite limit in a surprisingly short time. An increasing population doubles in size during an interval equal to 693 divided by the annual rate of increase, expressed in additional persons per 1,000 population [*see illustration on page 46*]. Thus in the period from A.D. 1 to 1750, when the growth rate was .56 per 1,000, the population doubled about every 1,200 years; in the next few decades, when a growth rate of about 20 per 1,000 is anticipated, the population will double in 34.7 years.

The cumulative effect of a small number of doublings is a surprise to common sense. One well-known illustration of this phenomenon is the legend of the king who offered his daughter in marriage to anyone who could supply a grain of wheat for the first square of a chessboard, two grains for the second square and so on. To comply with this request for all 64 squares would require a mountain of grain many times larger than today's worldwide wheat production.

In accordance with the same law of geometric progression, the human population has reached its present size through comparatively few doublings. Even if we again assume that humanity began with a hypothetical Adam and Eve, the population has doubled only 31 times, or an average of about once every 30,000 years. This is another way of saying that the peopling of the world has been accomplished with a very low rate of increase, when that rate is averaged over the entire history of the species. The average annual rate is about .02 additional persons per 1,000. Even when only the more rapid growth of the past 2,000 years is considered, the average rate is modest. Since A.D. 1 the population has doubled no more than four times, or about once every 500 years, which implies an annual rate of 1.4 persons per 1,000.

In the context of these long-term averages the rate of growth today seems all the more extraordinary, yet the source of this exceptional proliferation is in the conventional mathematics of geometric series. The population of the world increases to the extent that births exceed deaths; the growth rate is the difference between the birth rate and the death rate. Another way of stating the relation is that the average rate of increase, over a long period, is dependent on the ratio of the sizes of successive generations. This ratio is approximately equal to the average number of daughters born to women who pass through the span of fertile years multiplied by the proportion of women surviving to the mean age of childbearing. This product specifies the average number of daughters born during the lifetime of a newborn female, after making allowance for those women whose biological fertility is abnormal and for those who die before reaching the age of childbearing. When the product is 1—signifying one daughter per woman, under the prevailing conditions of fertility and mortality—successive generations are the same average size. When the product is 2, the population doubles with each generation, or about every 28 years.

The fertility of a population can also be measured by the number of offspring, both sons and daughters, born per woman during a lifetime of childbearing; this number is called the total fertility rate. Mortality is summarized by the average age at death, or the average duration of life, which is expressed as the expectation of life at birth. In 1973 the total fertility rate of American women was 1.94; the expectation of life at birth was 75 years. Thus women experiencing 1973 birth rates at each age would bear an average of 1.94 children, and women experiencing 1973 death rates at each age would have an average duration of life of 75 years.

When the average life span is short, the proportion of women surviving to the mean age of reproduction is small. In fact, among populations for which there are adequate data there is a close relation between these two numbers, and we can with some confidence estimate the proportion of women surviving to become mothers from the average duration of life. Another predictable characteristic of the human population is the ratio of male births to female births; for any large sample it is always about 1.05 to 1.

Because of these constant relations in the population it is possible to calculate all the combinations of female life expectancy and total fertility that will yield any specified growth rate. Of particular interest are the conditions producing zero population growth, since during most of the past million years the population has approached zero growth [*see illustration on page 45*]. In a static population the average duration of life is the

reciprocal of the birth rate. Expressed another way, in a population of constant size the birth rate is the number of births per person-year lived and the average duration of life is the number of person-years lived per birth.

There are many combinations of fertility and mortality that will just maintain a population at fixed size. Consider a static population in which the average duration of female life is 70 years. Given this mortality rate, the proportion of women surviving to the mean age of childbearing is 93.8 percent. Because the size of the population is to remain constant the average number of daughters born per woman must be 1/.938, or 1.066; since there are 1.05 male births for each female birth, the total fertility rate must be 2.05 × 1.066, or 2.19. The birth rate in such a population is 1/70, or 14.3 per 1,000 population.

If the average duration of female life is 20 years, as it probably was at times during the premodern period, then 31.6 percent of the women survive to the mean age of childbearing and those who live to the age of menopause have an average of 6.5 children; the birth rate under these circumstances is 50 per 1,000. (It should be pointed out that there is no inconsistency in the survival of many women to menopause in a population in which the average age at death is 20 years. When the death rate is high, the average age at death is not at all a typical age at death. When the life expectancy in a static population is 20 years, for example, about half the deaths occur before age five, about a fourth occur after age 50, and only about 6.5 percent occur in the 10-year span centered on the mean age at death.)

The importance of these relations is that they express the possible combinations of fertility and mortality that must have characterized the human population during each era of its history. If some other combination of fertility and mortality had been maintained for more than a few generations (as has happened during the past two centuries), the population would have expanded or contracted dramatically.

These combinations also determine the most extreme fertility and mortality rates possible in a static population. One limit is set by the minimum feasible mortality. When the average life expectancy is 75 years, 97.3 percent of all women survive to the mean age of reproduction, and it is necessary for them to have only 2.1 children [illegible] this represents a birth rate of 13.3 per 1,000. Any further reduction in mortality might raise the average duration of life to 80 years or more, but it would not significantly change the proportion of women surviving to childbearing age, nor would it much reduce the number of births per woman required to maintain the population. The other limit is imposed by fertility. When the life expectancy falls to 15 years, only 23.9 percent of all women live to have children, and those who do must have an average of 8.6 in order to prevent a decline in population. Although it is certainly biologically possible for a woman to bear more than eight or nine children, no sizable populations have been observed with total fertility much higher than eight births per woman.

Accurate records of human fertility and mortality are even more meager than records of numbers of people. Today fewer than half of the world population live in areas where vital statistics are reliably recorded; in most of Asia, almost all of Africa and much of Latin America, for example, the registration of births and deaths is inadequate. Precise information about fertility and mortality is therefore limited to the recent experience of the more developed countries, beginning in the 18th century in Scandinavia, the 19th century in most of the rest of Europe and the 20th century in Japan and the U.S. Much has been inferred about the present vital rates of underdeveloped countries from the age composition recorded in censuses, from the rate of population increase between censuses and from retrospective information collected in censuses and demographic surveys. For past populations, however, valid data on births and deaths are very rarely available, and they must therefore be derived by analyzing the forces that affect fertility and mortality.

Differences in fertility can be attributed to two factors: the differential exposure of women of childbearing age to the risk of childbirth through cohabitation with a sexual partner, and differences in the rate at which conceptions and live births occur among women who are cohabiting. In many populations the only socially sanctioned cohabitation is that between married couples, and thus the laws and customs governing the formation and dissolution of marriages influence fertility. A conspicuous example is the pattern of late marriage common until a generation ago in many Western European nations. For many years before World War II in Germany, Scandi[illegible] average age of first marriage for women was between 24 and 28, and from 1 to 30 percent remained unmarried at age 50. As a result the proportion of women of reproductive age who by being married were exposed to the risk of childbearing was less than half, and in some cases, such as Ireland, was as low as a third.

A much different nuptial custom that may also reduce fertility is common in areas of Asia and North Africa. Women are married at age 17 or 18, but the average age of the married male population is often eight or nine years greater than that of the married women. The fertility of some of the women is probably reduced by marriage to much older men, often widowers. Marriages are made by arrangement with the bride's parents, in many cases requiring the payment of a bride price, and older men are more likely to have the property or the prestige needed to claim the more desirable young women. Still another social influence on fertility is found in India, where Hinduism forbids the remarriage of widows. Although the prohibition has not always been scrupulously observed, it has doubtless reduced Indian fertility below what it might otherwise have been.

Among cohabiting couples fertility is obviously influenced by whether or not measures are employed to avoid having children. Louis Henry of the Institut National d'Études Démographiques has defined "natural fertility" as the fertility of couples who do not modify their behavior according to the number of children already born. Natural fertility thus defined is far from uniform: it is affected by custom, health and nutrition. Breast-feeding, for example, prolongs the period of postpartum amenorrhea and thereby postpones the resumption of ovulation following childbirth. In some populations low fertility can be attributed to pathological sterility associated with widespread gonorrheal infection. Finally, fertility may be influenced by diet, as has been suggested by the work of Rose E. Frisch and her colleagues at Harvard University. Age at menarche appears to be determined at least in part by the fat content of the body and is hence related to diet. Furthermore, among women past the age of menarche a sufficient reduction in weight relative to height causes amenorrhea. In populations with meager diets fertility may therefore be depressed. Because of the severe caloric drain of pregnancy and breast-feeding, it is probable that nursing prolongs amenorrhea more effectively in populations where the average body fat is near [illegible] needed for a regular reproductive cycle.

The most conspicuous source of differences in fertility among married couples today is the deliberate control of fertility by contraception and induced abortion. In some modern societies very low fertility rates have been obtained: the total fertility rate has fallen as low as 1.5 (in Czechoslovakia in 1930, in Austria in 1937 and in West Germany in 1973).

The prevalence of birth-control practices is known from the direct evidence of fertility surveys for only a few populations, and for those only during the past two or three decades. (The International Statistical Institute has begun a World Fertility Survey that should illuminate present practices but not those of the past.) Indications that fertility was deliberately controlled in past societies must be inferred from such clues as the cessation of childbearing earlier among women who married early than among those who married late. Evidence of this kind, together with the observation of a large reduction in the fertility of all married women, indicates that birth control was common in the 17th century among such groups as the bourgeoisie of Geneva and the peers of France. Norman Himes, in his *Medical History of Contraception,* has shown that prescriptions for the avoidance of birth, ranging from magical and wholly ineffective procedures to quite practical techniques, have been known in many societies at least since classical Greek times. A doctoral dissertation at Harvard University by Basim Musallam has demonstrated that *coitus interruptus,* a contraceptive method that compares in effectiveness with the condom and the diaphragm, was common enough in the medieval Islamic world to be the subject of explicit provisions in seven prominent schools of law. On the other hand, analysis of parish registers in western Europe from the 17th and 18th centuries and observations in less developed countries today suggest that effective birth-control practices are not common in most rural, premodern societies.

Large fluctuations in fertility, and in mortality as well, are not inconsistent with the long period of near-zero growth that characterizes most of the history of the population. Although the arithmetic of growth leaves no room for a rate of increase very different from zero in the long run, short-term variations were probably frequent and of considerable extent. In actuality the population that from our perspective appears to have been almost static for hundreds of thousands of years may well have experienced brief periods of rapid growth, during which it expanded severalfold, and thereafter catastrophic setbacks. The preagricultural population, for example, must have been vulnerable to changes in climate, such as periods of glaciation, and to the disappearance of species of prey. Once the cultivation of crops had become established the population could have been periodically decimated by epidemics and by the destruction of crops through drought, disease or insect infestation. Moreover, at all times the population has been subject to reduction by man's own violence through individual depredation and organized warfare.

Because earlier populations never expanded to fill the world with numbers comparable to the billions of the 20th century, we must conclude that sustained high fertility was always accompanied by high average mortality. Similarly, sustained low fertility must have been compensated for by low mortality; any societies that persisted in low fertility while mortality remained high must have vanished.

In the conventional outline of human prehistory it is assumed that at each earlier date the average duration of life was shorter, on the principle that early man faced greater hazards than his descendants. It is commonly supposed, for example, that hunters and gatherers had higher mortality than settled agriculturists. The greater population attained by the agriculturists is correctly attributed to an enhanced supply of food, but the appealing inference that reduced mortality was responsible for this acceleration of growth is not necessarily justified.

The advent of agriculture produced only a small increment in the growth rate; if this increment had been caused by a decline in mortality, the change in the average life expectancy would have been hardly noticeable. If in the hunting-and-gathering society the average number of births per woman was 6.5, for example, the average duration of life must have been 20 years. If the fertility of the early cultivators remained the same as that of their predecessors, then the increase in the life span required to produce the observed acceleration of growth is merely .2 year. The increase in life expectancy, from 20 to 20.2 years, would not have been perceptible.

If one assumes that preagricultural man had substantially higher mortality than the early cultivators, it must also be assumed that the hunters and gatherers had much higher fertility. If the earlier culture had an average age at death of 15 instead of 20, for example, then its fertility must have been 6.6 births per woman rather than 6.5. Such a change is unthinkable; the complete reorganization of life represented by the adoption of agriculture could certainly be expected to influence both fertility and mortality. There is reason to suspect, however, that both vital rates increased rather than decreased [*see illustration on next page*].

Both disease and unpredictable famine might have increased the death rate of the first cultivators. Village life, by bringing comparatively large numbers into proximity, may have provided a basis for the transmission of pathogens and may have created reservoirs of endemic disease. Moreover, the greater density of agricultural populations may have led to greater contamination of food, soil and water. Greater density and the more or less total reliance on crops may also have made agriculturists extremely vulnerable to crop failure, whereas the hunting-and-gathering culture may have been more resistant to adversity.

If mortality did increase on the introduction of agriculture, then it is certain that fertility also rose, and by a slightly larger margin. The supposition that both vital rates did increase is supported by observations of the fertility rates of contemporary peoples who maintain themselves by hunting and gathering, such as the Kung tribe of the Kalahari Desert in southwestern Africa. Nancy Howell of the University of Toronto, analyzing observations made by her and by her colleague Richard Borshay Lee, has found that Kung women have long intervals between births and moderate overall fertility. A possible explanation, suggested by the work of Rose Frisch, is that the Kung diet yields a body composition low enough in fat to cause irregular ovulation. Interbirth intervals may be further prolonged by protracted breast-feeding combined with low body weight. If such conditions were common among preagricultural societies, the cultivation of crops could have increased fertility by increasing body weight and possibly by promoting the earlier weaning of infants so that mothers could work in the fields.

Unfortunately these speculations on the demographic events that may have accompanied the Neolithic revolution cannot be adequately tested by direct evidence. Until relatively recent times the only available indicators of mortality rates were tombstone inscriptions and

the age-related characteristics of skeletons. Because the sample of deaths obtained in these ways may not be representative, it is not possible to reliably estimate for early periods such statistics as the average duration of life.

The accelerated growth in the world population that began in the 18th century is more readily understood if the areas classified by the UN as "more developed" and "less developed" are considered separately.

A general description, if not a full explanation, of the changing rates of increase in the more developed areas since the 18th century is provided by what demographers call the demographic transition. The changes in fertility and mortality that constitute the demographic transition are in general expected to accompany a nation's progression from a largely rural, agrarian and at least partly illiterate society to a primarily urban, industrial and literate one. Virtually all the populations classified by the UN as more developed have undergone demographic changes of this kind, although the timing and extent of the changes vary considerably.

The demographic experience common to all the more developed countries includes a major reduction in both fertility and mortality at some time during the past 200 years. In the 18th century the average duration of life was no more than 35 years, and in many of the nations that are now counted among the more developed it must have been much less. Today, almost without exception, the average life expectancy in these nations is 70 years or more. Two hundred years ago the number of births per woman ranged from more than 7.5 in some of the now more developed areas, such as the American colonies and probably Russia, to no more than 4.5 in Sweden and probably in England and Wales. In 1973 only Ireland among the more developed countries had a fertility rate that would produce more than three children per woman, and in most of the wealthier nations total fertility was below 2.5. Thus virtually all the more developed nations have, during the past two centuries, doubled the average life expectancy and halved the total fertility rate.

If the decline in fertility and mortality had been simultaneous, the growth in the population of the developed countries since 1750 might have been modest. Indeed, that was the experience of France, where the birth rate as well as the death rate began to decline before the end of the 18th century. As a consequence the increase in the French population was much less than that of most other European nations. The combined population of the developed countries experienced extraordinary growth after 1750, however, a growth that accelerated until early in the 20th century. The reason for the increase in numbers is that the decline in mortality has in almost all cases preceded the decline in fertility, often by many years [*see illustration on opposite page*].

The decline in fertility in the U.S., as in France, began early; it appears to have been under way by the beginning of the 19th century. Because of early marriage, however, fertility in the U.S. had been very high, so that the excess of births over deaths was still quite large. In most of the other more developed countries the birth rate did not begin to fall until late in the 19th century or early in the 20th.

Another universal feature of the transition is a change in the stability of the vital rates. In the premodern era the high birth rate was relatively constant, but the death rate fluctuated from year to year, reflecting the effects of epidemics and variations in the food supply. In those countries that have completed the demographic transition this pattern is reversed: the death rate remains constant but fertility varies considerably.

The causes of the event that began the demographic transition—the decline in mortality in the late 18th century—are a matter of controversy to social and medical historians. According to one school of thought, until the middle of the 19th century medical innovations in England could not account for the reduction of the English death rate; the principal factor proposed instead is an improvement in the average diet. Others argue that protection from smallpox through inoculation with cowpox serum, a procedure introduced late in the 18th century, was sufficient to markedly reduce the death rate. They propose that the further decline in mortality in the early 19th century may have been brought about by improvements in personal hygiene.

A third hypothesis is that before the 18th century fortuitous periods of low mortality were not exceptional, but that they were followed by periods of very severe mortality caused by major epidemics. According to this view, the late 18th century was a normal period of respite, and improved conditions early in the 19th century averted the next [illegible] epidemics, which would otherwise have produced a recurrence of high mortality rates.

Whatever the cause of the initial decline in the death rate, there is no doubt that subsequent improvements in sanitation, public health and medicine made possible further reductions during the 19th century; indeed, the process continues today. It is equally clear that the reduction in mortality was dependent on the increased availability of food and other material resources. This rise in living standards was in turn brought about by the extension of cultivation, particularly in the Western Hemisphere, by increased productivity in both agriculture and industry and by the development of efficient trade and transportation.

The decline in the birth rate that eventually followed the decline in the death rate in the more developed countries was, with the exception of late-19th-century Ireland, almost entirely a decline in the fertility of married couples and can be attributed directly to the practice of contraception and abortion. The reduction in fertility was not a result of the invention of new contraceptive techniques, however. Among selected Americans married before 1910, English couples interviewed in the 1930's and couples surveyed in France and several eastern European nations after World War II, the principal method of birth control was *coitus interruptus*, a technique that had always been available. The birth rate declined because the perceived benefits and liabilities of having more children had changed, and perhaps also because the couples' view of the propriety of preventing births had been modified.

Reduced fertility can be considered one of the consequences of the characteristics by which the more developed countries are defined. In an urban, industrial society the family is no longer the main locus of economic activity, nor are children the expected means of support in old age. In an agrarian, preindustrial society, on the other hand, the family is a basic economic unit and sons are a form of social security. Moreover, in the less developed countries the costs of raising and educating a child are minimal; indeed, a child may contribute to the welfare of the family from an early age. In the industrial society child labor is prohibited, education is compulsory and it often extends through adolescence. These conditions conspire to discourage couples in the more developed countries from having large families [illegible] established agrarian so-

cieties social norms supporting child-bearing tend to be perpetuated.

In the less developed countries the estimated rate of population growth was virtually zero until about 200 years ago, when a moderate rate of increase, about four per 1,000, was apparently induced by a reduction in mortality [*see illustration on page 47*]. The cause of this reduced death rate is uncertain. Durand has suggested that the interchange of staple foods between regions that had previously been isolated might have contributed to population growth in Asia and in Europe as well. In particular the introduction of the potato into Europe and of maize and the sweet potato into China have been cited as possible contributing factors.

Since the aggregate population of the less developed countries includes many large areas that have not been reliably enumerated, a description of the historical course of population growth in these countries is subject to much uncertainty. A slight reduction in the average rate of increase in the latter half of the 19th century, for example, can be attributed entirely to an estimated zero rate of growth in China, and that estimate is based on uncertain data. There is no doubt, however, that in the poorer nations rapid growth began in the 1920's, 1930's and 1940's, and that since World War II the population increase has accelerated dramatically.

The enormous recent growth of the populations of the less developed nations can be interpreted in terms of the demographic transition, but some parts of the process have been more rapid and more extreme than they were in the industrial nations; moreover, the transition is not yet complete, and its future course cannot be predicted. Mortality has dropped precipitously, but fertility has so far remained unchanged or declined only moderately. In the combined populations of the less developed countries the number of births per woman is about 5.5, and the average duration of life is more than 50 years, yielding an annual growth rate of about 25 per 1,000. Since World War II mortality in the less developed countries has fallen much more quickly than it did in 19th-century Europe, largely because modern technology, and particularly medical technology, can be imported more rapidly today than it could be discovered and developed 100 years ago. Insecticides, antibiotics and public health measures that were unknown during the European demographic transition are now commonplace in the less developed countries.

According to estimates prepared by the UN, the average duration of life in the less developed areas has risen from 32 to 50 years during the past three decades, an increase of 56 percent. During the same period the birth rate is estimated to have declined by no more than 7 to 8 percent. The actual fall in fertility is in fact even less, by about 4 percent, since demographic changes have reduced the proportion of women in the childbearing years. (Although the fertility of the less developed countries as a group remains very high, there are some countries where the birth rate has fallen significantly—by from 25 to 50 percent—and very rapidly. They include Hong Kong, Singapore, Taiwan, South Korea, West Malaysia, Barbados, Chile, Cuba, Jamaica, Trinidad and Tobago, Puerto Rico and Mauritius. According to reports from travelers, there has also been a decline in fertility in China, particularly in the cities.)

The present rapid growth in the world population is a result of a high rate of increase in the less developed areas and a moderate rate in the rest of the world. According to projections prepared by the UN, more than 90 percent of the increase in population to be anticipated by 2000 will be contributed by the less developed nations, even though a large reduction in fertility in these countries is expected in the next 25 years. The future course of the world's population depends largely on demographic trends in these countries.

The events of the demographic transition provide no sure way of calculating when or how quickly fertility will decline in the less developed nations. The experience of the industrial world is not a satisfactory basis for prediction. The history of the Western population during the past 200 years suggests that vital rates normally fall as a concomitant of modernization, but it provides no checklist of advances in literacy, mortality reduction and urbanization that would enable one to estimate when fertility will fall. In the more developed world there are instances of large reductions in fertility in populations that were still rural, mostly illiterate and still subject to moderately high mortality, as in the Garonne valley in southwestern France before 1850. In other instances fertility did not decline until after education was almost universal, the population was mostly urban and agriculture had become the occupation of a small minority, as in England and Wales.

The present rate of world population increase—20 per 1,000—is almost certainly without precedent, and it is hundreds of times greater than the rate that has been the norm for most of man's history. Without doubt this period of growth will be a transitory episode in the history of the population. If the present rate were to be maintained, the population would double approximately every 35 years, it would be multiplied by 1,000 every 350 years and by a million every 700 years. The consequences of sustained growth at this pace are clearly impossible: in less than 700 years there would be one person for every square foot on the surface of the earth; in less than 1,200 years the human population would outweigh the earth; in less than 6,000 years the mass of humanity would form a sphere expanding at the speed of light. Considering more realistic limits for the future, if the present population is not multiplied by a factor greater than 500 and thus does not exceed two trillion, and if it does not fall below the estimated population of preagricultural society, then the rate of increase or decrease during the next 10,000 years must fall as close to zero as it was during the past 10,000 years [*see illustrations on opposite page*].

Arithmetic makes a return to a growth rate near zero inevitable before many generations have passed. What is uncertain is not that the future rate of growth will be about zero but how large the future population will be and what combination of fertility and mortality will sustain it. The possibilities range from more than eight children per woman and a life that lasts an average of 15 years, to slightly more than two children per woman and a life span that surpasses 75 years.

The Populations of the Developed Countries

These populations, a little more than a fourth of the human species, may be well on the way to long-term numerical stability. This state of affairs appears to have been achieved largely by personal choice

by Charles F. Westoff

One result of man's social evolution has been the rise of a group of populations living in countries commonly described as developed. The populations of these countries enjoy better health, longer life, better education, wider occupational opportunities and a greater variety of amenities than the populations of less fortunate lands. If it is true that a third or a fourth of the human race still go to bed hungry every night, it is also true that a large fraction of a billion people now have access to a kind of life that two centuries ago was known to only a privileged few.

Understandably the inhabitants of underdeveloped lands look to the day when their own country will cross the imaginary and elusive line that separates the haves from the have-nots. In 1974, measured in terms of the steadily depreciating U.S. dollar, that line might be represented by an annual per capita income of something like $750. Comparable figures for an inhabitant of the U.S. or Sweden are between $4,000 and $5,000.

If the line separating the haves and the have-nots is elusive, it is sharply drawn in demographic terms. In developed countries the average life expectancy at birth has climbed to more than 70 years compared with about 50 years in the underdeveloped countries. Much of the difference is attributable to high infant mortality: anywhere from 50 to more than 250 deaths per 1,000 births in underdeveloped regions as against fewer than 25 deaths per 1,000 in most developed countries.

The demographic index that probably has the greatest significance for mankind in the long run is the rate of population growth. It too shows a sharp line of demarcation between the underdeveloped and the developed regions of the world. The former have high population growth rates (averaging 2.5 percent per year) whereas the latter have rates that not only are low (less than 1 percent) but also are still falling. In fact, among 30-odd countries that can reasonably be described as developed, the fertility rate is at, near or below the replacement level in the 20 that have 80 percent of the world's total developed population. If these low fertility rates continue for two generations, population growth will cease and the developed world will reach zero population growth, the culmination of a historical process in which birth rates slowly fall to the low magnitudes of the death rates achieved some generations earlier. The balancing of these vital rates at very low levels can be viewed as the end of a major demographic transition, a process involving the entire economic development and accompanying transformation of social institutions that can be called for want of a better term modernization.

Before one predicts too confidently that the end of the demographic transition is in sight, however, one must recall that the same was predicted once before, back in the 1930's when the rates of population growth in the industrialized countries of the world had reached all-time lows. That the next generation of parents did not exactly follow the script of the demographers is now all too clear and has proved a continuing source of embarrassment to the experts.

From one point of view the fact that the demographic transition appears to be entering its terminal stages a generation later than was predicted could be regarded as no more than a slight interruption in a long historical process. On the other hand, the "baby boom" that occurred in many of the developed countries during the late 1940's and subsequent years has already added more than 10 percent to the populations of those countries: nearly 100 million more people who are now themselves reaching the age of parenthood and who constitute an enormous potential for a second baby boom. At the beginning of World War II the combined population of the then developed world—the U.S., Europe (including all the U.S.S.R.), Canada, Australia and New Zealand—stood at about 720 million. If the expectations of demographers had materialized, the population of these countries today would be around 845 million instead of the currently estimated 940 million.

One can disagree about the list of countries that can be described as de- [illegible] purposes of this article

"LE MOULIN DE LA GALETTE," a detail of which is reproduced on the opposite page, was painted by Pierre Auguste Renoir in 1876. It suggests, among many other things, the good life of the healthy, well-fed inhabitants of a developed country. The Moulin de la Galette (a free translation might be the Cake Mill) was an open-air establishment where Renoir went on Sunday. He disliked working with professional models, and so he recruited models here. Two of them who were sisters appear in the right foreground. The other principal [illegible]

I have selected 31 nations, representing most of the conventionally developed countries of the world, including all the nations of Eastern Europe, plus Portugal, Spain, Greece, Japan and Israel. I have omitted Venezuela and Argentina, which have per capita gross national products substantially higher than the poorest of the European countries (Portugal and Yugoslavia), because their vital statistics are incomplete. The oil-rich countries of the Middle East are also excluded because they still lack most of the characteristics of industrialized nations in spite of their high per capita gross national products. Hong Kong, which has a population of about 4.5 million, could probably also qualify today as a developed country but its records too are inadequate.

It is appropriate to concentrate on fertility and ignore mortality because death rates are uniformly low in the developed countries; thus population growth in the aggregate depends mainly on the future course of fertility. I have selected the "total fertility rate" from among various alternative measures because it summarizes several demographic dimensions simultaneously in a single number that has familiar properties: the average number of births per woman. More precisely, the total fertility rate can be regarded as the average number of births women would have as they pass through to the end of their childbearing years provided that they continue to reproduce at the observed rates for women at different ages as determined for any given year. If the total fertility rate persisted at approximately 2.1 births per woman, what demographers refer to as replacement fertility, then each generation would merely replace the next and eventually (after the effects of the disproportionately larger numbers of young people due to past growth diminished) birth rates would equal death rates and the population would stop growing (apart from immigration). The time required to reach a zero rate of natural increase varies, depending on the history of past growth. Some countries, most recently West Germany, have already dropped below zero natural increase; others, such as Australia and New Zealand, have a long way to go both because of their more youthful age structures and because their fertility rates, although declining, are still well above replacement.

As a demographic index the total fertility rate shares the inherent problem of any period rate used as an indicator of future trends. The "if" in one of the demographer's most frequent statements, "If current trends continue...," is pat[illegible] by glancing at the variations over a period of time in the different countries.

Not only is the reproductive behavior of people difficult to predict, except very roughly, but also a measure of fertility for a given period of time can be misleading because the magnitude of fertility can be confused with the timing of births. The currently low fertility rates in some countries may imply only a postponement of childbearing that could be made up in later years, resulting in an underestimate of the completed fertility of those women. Finally, the overall rate is the simple sum of the rates for all ages within the range of reproductive years and thus can obscure countervailing trends among younger and older women.

Since World War II the trend in fertility in the developed world has followed a variety of patterns in different regions. To summarize these patterns the 31 selected countries of the developed world are divided here into eight different regional or cultural groupings [*see illustrations on these two pages*].

The U.S., Canada, Australia and New Zealand (current total population 250 million) experienced sustained baby booms from the end of the war, rising through the next decade and reaching highs ranging from 3.5 to 4.2 births per woman in the four countries. These baby booms added about a third more people to the 1970 population of these countries than hypothetically would have been added if the prewar fertility rates had continued. This historically unprecedented increase has been followed in the past decade or so by a dramatic and continuing decline, which has set record lows in the past two years. In the U.S. and in Canada the fertility rates declined by nearly 50 percent in 15 years, down to fewer than two births per woman by 1973. If this below-replacement level in the U.S. were to continue unchanged, the population would stop growing in less than two generations and would begin to decline, unless it was bolstered by immigration. Even if immigration were to continue at its current level (a net of some 400,000 per year), any further drop below the 1973 fertility rate would still lead ultimately to a population decline.

The pattern in Western Europe has been different. Britain, France, Belgium and the Netherlands (current total population 130 million) experienced only a temporary rise in fertility immediately after the war, followed by a resumption of the downward movement for five years or so and then a gradual increase in fertility (a fairly marked increase in England and Wales from 2.2 births per woman in 1951 to 2.9 in 1964), followed by another decline continuing to the present. Italy, grouped in the charts with Spain, Portugal and Greece (current total population 110 million), exhibited a fertility pattern closely resembling that of its northern neighbors. In Portugal, by way of contrast, the fertility rate is unusually stable: there are only small annual fluctuations around an average of three births per woman, with some suggestion of an overall downward trend. The records for Spain and for Greece are less extensive, but the recent experience in these two countries shows a fairly stable fertility at quite different levels: Spain hovers just below three births per woman and Greece just above two births per woman.

Ireland, although grouped with its British neighbors in the charts, has a fertility pattern that is unique among the 31 nations in the postwar period. (Ireland's population is only three million.) Superficially the trend, based on incomplete data, corresponds more closely to that of the overseas English-speaking populations of European origin (the U.S., Canada, Australia and New Zealand) than it does to that of Britain, at least through 1960, except that there is no evidence of any recent sustained decline. Irish fertility has remained just under four births per woman.

The Central European countries of Austria, Switzerland and the two Germanys (total population 93 million) have followed a pattern similar to that of the countries to their west, at least since 1955. There was a gentle rise in fertility, peaking at levels between 2.5 and 2.8 births per woman and then declining rapidly. The total fertility rate of 1.5 births per woman in West Germany is unquestionably the lowest in the world. All four of these Central European countries are now significantly below population replacement.

The Scandinavian countries, except for Sweden, which escaped the war, experienced a brief postwar baby boom, followed by patterns very similar to those of Central and Western Europe. Norway was slightly anomalous in showing an increasing rate for a decade, beginning in the early 1950's. The decline in Finland has been precipitous, from 3.5 births per woman in the immediate postwar years to an estimated 1.8 in 1973. Fertility in all the Scandinavian countries (total population 22 million) is now below the replacement level except in Norway,

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which at the current rates of decline will join its neighbors demographically in a few years.

According to a recent analysis by Arthur A. Campbell of the National Institute of Child Health and Human Development, most of the rise in fertility in the developed countries during the postwar period was due to increases in the fertility of women in the younger age groups, resulting in a significant decline in the average age of childbearing. Involved in this change were sharp increases in proportions of women marrying at younger ages. The baby boom was therefore to a large extent a result of changes in the age distribution of childbearing rather than of changes in completed fertility; it was clearly not a return to the large families of earlier times.

The U.S.S.R. and the other countries of Eastern Europe (total population 356 million) reveal a different pattern of a fairly uniform decline in fertility, aided by the wide availability of abortion, reaching very low levels earlier than the other developed countries. In some years the number of abortions has exceeded the number of births. In Hungary the total fertility rate had dropped to 1.8 births per woman by 1962, when the U.S. rate, for example, was still at 3.5. Romania's fertility dropped precipitously from 3.1 births per woman in 1955 to 2.0 by 1962 and to a low of 1.9 in 1966. In that year the Romanian government, alarmed at the rapid decline, reversed its permissive abortion law, with the result that the fertility rate doubled to 3.7 the following year. The liberalization of abortion laws in Eastern Europe had been intended primarily to promote maternal health and to facilitate the employment of women, but the resulting low rates of population growth have caused official anxiety. Since the tightening of the abortion law in Romania fertility has once again resumed its decline as contraception and illegal abortion have taken the place of legal abortion.

The data for the U.S.S.R. are incomplete. Postwar fertility records begin only with 1957, when the rate was 2.8 births per woman. The trend during the following decade was slowly downward, but the fertility rate seems to have stabilized at around 2.5 births per woman in the past several years, which is higher than that of any of the other Eastern European countries except Romania. According to other evidence, the European regions of the U.S.S.R. have a fertility rate quite similar to that of other European countries; it is the high fertility of the Asian regions that accounts for the higher overall national rate.

The two developed Eastern countries of Poland and Yugoslavia have experienced radical declines in fertility since the war. In Poland the rate dropped from 3.7 births per woman in 1954 to 2.2 in 1969; in Yugoslavia the rate dropped from a high of 4.3 births per woman in 1952 to 2.3 in recent years.

Only the Jewish population of Israel (2.8 million of a total population of 3.2 million) is included in this review because of the enormous differences, demographic and otherwise, between the Jewish and the Arab components of the country's total population. In 1972 the total fertility rates for the Jewish and the Arab populations were respectively 3.2 births per woman and 7.3. A demographic cynic has recently calculated that if current trends continue, the Jewish population will be a minority in Israel within three generations. Although Jewish fertility is changing slowly, its trend is clearly downward, and it will probably continue to decline during the remainder of this decade. It is nevertheless considably higher than the estimated rate for the Jewish population in the U.S. For that matter, it is probably higher than that for Jewish populations in any developed nation.

The last country on the list, Japan (population 108 million), has been frequently referred to as the modern demographic miracle and an example of what the introduction of a permissive abortion law can do to the birth rate of a population that practices little contraception. Japan's total fertility rate dropped from 4.5 births per woman in 1947 to 2.0 a decade later. As the curve in the illustration at the right on page 111 shows, the rate fell to 1.6 births per woman in 1966. That was the Year of the Fiery Horse, which comes every 60 years. According to Oriental astrology, girls born that year may murder their husbands, which tends to reduce their marriageability. Japanese parents evidently decided to cut their chances of having a girl child in 1966. Japanese fertility is now still around replacement, having climbed slightly above the rates prevailing in most of the preceding decade.

The variety of patterns in these 31 countries should not obscure the central and most important fact that fertility in most of the developed world has virtually collapsed. Only New Zealand (in which fertility has been declining), Ireland, Spain, Portugal and the Jews of Israel still have relatively high rates, ranging between 2.8 births per woman and 3.9. In 20 of the 31 countries the rate is now below, in some cases substantially below, the replacement level of 2.1 births per woman; it appears to be headed in that direction or hovering around 2.3 births in most of the remaining 11 countries. The average fertility rate for all 31 countries is currently 2.3 births per woman. If the figure is weighted for population, the average drops to 2.2 for the total population of the developed world. The population growth rate in all but a few developed countries is now less than 1 percent.

What lies ahead? Will fertility stabilize at replacement levels? Or will it continue to decline, resulting in the prospect of populations of rising average age and actual declines in numbers sooner or later? Although it seems unlikely now, it is also quite possible that fertility rates could do an about-face and rise again. These are not easy questions to answer, and one should approach any portrait of the future with particular hesitancy in view of the failure of prediction in the 1930's, when fertility was at similar low levels.

We should continually remind ourselves that the evidence we have to rely on, annual total fertility rates, can be quite misleading as a guide to the long-range behavior of women passing through three decades of reproductive life. What can be postponed today can be made up tomorrow. Nevertheless, there is some independent evidence in support of the inference that the current low fertility rates indeed reflect the longer-range intentions of younger couples. Fertility surveys were conducted in 10 developed countries between 1966 and 1972; married women were asked the number of children they wanted or expected to have. When their replies are tabulated by the number of years they have been married, there is a clear decline in the anticipated number of children for women married before 1951 as opposed to those married since 1966, which is quite consistent with the picture of decline presented by the series of annual rates.

For example, the women in the Finland survey, married for 20 years or longer, expected a total of four births, whereas those married five years or less expected to bear only two children. A similar decline in the U.S. was evident by 1970, from 3.5 births for those married 20 years or more down to 2.5 among newly married women. A further decline to 2.2 was found in a 1972 survey. Comparable low values were recorded for recently married women in Belgium (2.1), Czechoslovakia (2.2), Poland (2.2),

France (2.1), Yugoslavia (2.1), Hungary (1.9) and England and Wales (1.9). Even in Turkey, a country not included among the developed nations of the world, the average number of births expected had declined from 6.6 for women married for 20 years to 3.8 for those most recently married. Of course, these expectations might well increase as the younger women grow older and experience unplanned pregnancies.

The same surveys revealed, however, that an average of more than 80 percent of the women in these countries (excluding Turkey) who were exposed to the risk of pregnancy were currently practicing birth control. Improved contraceptive methods are widely available, the practice of sterilization has become increasingly common in a few countries (in the U.S. it has become the most popular method among couples with wives aged 30 to 44) and legalized abortion has become more available for situations where contraception fails. This does not mean that unplanned and unwanted pregnancies have disappeared or even that they are about to disappear. The practice of male withdrawal was the most common method used by couples in half of the countries surveyed; the modern methods of contraception are far from universally available. It does mean, however, that the small families expected by younger couples today have a greater chance than ever before of being realized.

The pervasiveness of the decline of fertility throughout the developed world should caution us against invoking currently fashionable causal explanations such as the women's rights movement, the "pill," "zero population growth" or the recent concern for the environment, although these factors have undoubtedly played a role in some countries, such as the U.S. and Canada. One can think of particular factors relevant to fertility that have operated in certain countries, such as abortion in Japan and a chronic housing shortage coupled with easy abortion and a demand for women in the labor force in Eastern Europe. A more persuasive case can be made, however, by taking the long-term historical view that links the demographic transition with the development of an industrial society, with secularization, with education and with the emergence of the demands of the individual over and above those of the family and the community. This transition has been proceeding in the U.S. and France since about 1800 and in the rest of Europe for about a century.

Although the pill [illegible] and legalized abortion are appealing as ready explanations of the low fertility rates of recent years, one should remember that the rates were even lower in the 1930's. With only a few exceptions every Western European nation recorded total fertility rates at or considerably below the replacement level (as low as 1.5 births per woman in Czechoslovakia and Austria), and this was before abortion was readily available and before the modern methods of contraception appeared. Fertility was also at the replacement level in the U.S., Australia and New Zealand. Evidently the motivation to control reproduction was so intense in those years that delays in marriage, illegal abortion, abstinence (probably) and the more effective use of conventional contraceptive methods combined to produce the lowest fertility in history. Granting that the Great Depression may have contributed to the rapidity and depth of the decline, the fact remains that if one projected the fertility rates of the 1930's from previous trends, the curve would look much like what actually happened. From this perspective the phenomenon that still remains to be satisfactorily explained is not the decline in fertility of the past 15 years, which is part of a longer historical process, but rather the baby boom, which was particularly sustained in the English-speaking populations of European origin.

One certainty about future population trends in the developed world is that the rate of natural increase will not be exactly zero. As fertility becomes increasingly subject to voluntary control—the closer we approach the situation in which every child born is planned—the more vulnerable annual fertility rates will be to short-term variation. My guess is that we can expect swings in fertility rates of five to 10 years' duration, ranging perhaps from as low as 1.5 births per woman to as high as 2.5 as fertility responds to short-term economic changes and to various other changes in ideology and fashion. There is no reason in principle that fertility could not rise above or fall below this range in some countries, but it seems unlikely that the developed world as a whole will experience such wide swings. It is also unlikely that the swings will be anywhere near as violent as the Romanian experience, where the number of births in 1967 was double the number in 1966. This bumper crop of babies is now creating overcrowding in the Romanian school system, and beginning in 1984 there will probably be severe unemployment as an out-migration [illegible] 1967 cohort begins to enter the labor force at age 18. If one wanted to draw a demographic blueprint for a meritocracy, it would feature a uniform stream of births from year to year in order to equalize opportunity. The avoidance of large swings would eliminate both the competitive advantages enjoyed by small numbers in great demand and the disadvantages experienced by those born in years when birth rates were high, who are forced to compete for limited opportunities and rewards.

Even if replacement fertility for the developed world as a whole were maintained for the foreseeable future beginning in the 1980's, the population, because of the age composition resulting from its past history of growth, would increase by more than a fourth, adding some 300 million more people. Of that total about two-thirds would have been added by the year 2000. Of course, if fertility remained below the replacement level, the end of population growth would come sooner and would result in a smaller increment. Although it is possible that this may happen, it does not appear too likely at this juncture. The demographic situation seems to be changing so rapidly, however, that what appeared likely a scant five years ago no longer appears so, and by the same logic today's picture may appear badly out of focus from the perspective of 1980.

What does seem plausible today is that the population of the developed world will average replacement fertility by the early 1980's. If that level is continued in the future, the developed population will continue to increase for a good part of the next century, stabilizing just below 1.5 billion. Apart from the effects of the sheer increase in numbers (half a billion more than today), the age structure of the population will change in several significant respects. The proportion of youths—those under 20 years of age—will decline from roughly a third to a fourth of the total by the time the population stops growing, but because of the increasing population base the number of young people will remain about the same as it is today. The number of aged people—those 65 and over—will increase dramatically from about 120 million to 175 million by the year 2000 and to 275 million in the stationary population; now 11 percent of the total population, this age group will ultimately constitute 19 percent. The increase of 55 million aged people that will take

place by the end of the century is not a matter of conjecture; they will be the survivors of people 40 and over who are alive today. For societies that do not seem to have been doing an outstanding job in the integration of the aged, the prospect of such growth is sobering.

The age structure of the population that is in prospect for most developed countries is foreshadowed in Sweden and a few other countries that have experienced very low rates of growth for a long period of time. Some observers have maintained that older populations will discourage innovation and will be more conservative, less exciting societies in which to live. Others who have lived through recent excesses of youth feel less apprehensive about the prospect. Little is actually known about the effects of age composition per se because its change is relatively slow and is intertwined with numerous social and economic factors that become part of the total process. The components of broad social change cannot be so neatly disentangled that the social scientist can isolate age composition as a determinant of other changes. One advantage is that the prospect of an increasing number of older people is completely predictable; the governments of the developed countries therefore have time to plan their accommodation. Regrettably, governments in general are not noted for their capacity for long-range planning.

After another generation or so of continued low fertility many developed countries will have reached the point where below-replacement fertility will mean an absolute decline in numbers, such as both West Germany and East Germany are now experiencing. When that happens, and probably long before, the occasional cries of alarm we now hear about labor-force needs or national security or national virility will increase in both number and volume.

How do governments react to population change? Most of the talk about population has understandably focused on the problems of growth in the developing countries. Back in the late 1930's population was on the mind of a country such as Sweden that was facing an impending decline in numbers, resulting in one of the first modern population policies. Population was also a matter of great interest to the German and Italian governments for different reasons. France, which had long been sensitive to problems of national security, had earlier enacted pronatalist legislation designed to strengthen the family. Apart from these sporadic displays of interest, however, the subject of population has never been high on the agenda of national priorities.

A similar, although perhaps changing, situation obtains today. In general the subject of population is not a pressing one in the government offices of the developed countries. The topic seems to emerge only when the aggregate consequences of individual behavior are perceived to threaten the national welfare. Thus the U.S. and Australia formed national panels to inquire into population as environmental problems became linked with population. Britain recently established an "inquiry" and the Netherlands a royal commission to evaluate the consequences of expanding populations. Ironically a royal commission in Britain and an official committee in the U.S. had been appointed only a generation earlier because of concern about the threat of a declining population. Japan has had a population advisory panel for several years; Israel, with its political concerns both about its numbers in relation to its hostile neighbors and about the different growth rates of ethnic segments of its own population, has had a Committee for Natality Problems for more than a decade. Virtually all developed countries have or have had some official group concerned with population (frequently in connection with labor migration), but few can be said to have articulated what might be termed explicit population-growth policies and programs. The World Population Conference, held this summer in Bucharest, has stimulated the development of population policy if for no other reason than that the official delegations were expected to take positions on a draft "World Population Plan of Action."

On balance, the direction of official thinking on the subject in the developed countries is pronatalist. For the most part the official attitude is to promote family welfare for various reasons largely unrelated to fertility but with the expectation, or hope (the little evidence that exists is not reassuring), that by reducing the costs of parenthood through family and child allowances, maternity benefits and sundry other benefits couples may be less reluctant to have another child.

Fertility and population growth are not the sole reasons for official concern. The increasing concentration of population in metropolitan areas presents special problems; also in some countries the depopulation of rural areas is worrisome. From time to time the desirability of immigration has loomed large in the thinking of Australia, Britain, Canada, Israel, New Zealand and the U.S. Other countries [illegible] Finland, Greece, Ireland and Sweden, have long been concerned about the loss of population through emigration. Some countries, such as the Netherlands, Switzerland and West Germany, are concerned about the problem of accommodating foreign workers.

By and large, however, the pronatalist sentiments of most of the developed countries are motivated by the impending threat of a declining population. Some countries, such as Japan, are concerned about the economic implications of declining numbers of young workers. The countries of Eastern Europe are similarly worried about the economic consequences of periods of low fertility. Other countries have nationalistic anxieties—an attitude that never lies much below the surface. For example, shortly before his death President Perón of Argentina announced a pronatalist population policy because of the rapid population growth of some of Argentina's neighbors. He made oral contraceptives illegal and reminded Argentine women of their maternal responsibilities.

That harsh response, however, is exceptional. Most pronatalist "policies" do not preclude the availability of contraceptive supplies or, in some instances, abortion services. A survey of 24 developed countries made by Bernard Berelson of the Population Council shows that before Perón's action only Ireland interposed legal obstacles to distribution of contraceptives, and this now appears to be changing. About half of the countries in Berelson's review had provisions for legal induced abortion, although they varied in the degree of permissiveness. Therefore, in spite of the pronatalist orientation of most of the developed countries, the majority of governments provide fertility-control services in public health programs.

What will happen if fertility continues to decline, or if population actually begins to drop, is another matter. It seems unlikely, however, that there will be any wholesale removal of family-limitation supplies or services. These apparent conflicts in policy underscore the fact that fertility-control policies were prompted in earlier days primarily not by demographic considerations but rather by concern over women's health and, in some instances, women's freedom of choice, and by the desire to achieve economic objectives by enabling women to work. There has been talk in some governments (for example Japan's) about tightening permissive abortion laws, and in recent months Czechoslovakia and Hungary have narrowed the conditions under which abortions can be obtained. [illegible] concern both about

very low fertility and about rising rates of premature births resulting from earlier abortions. Both countries are nonetheless promoting alternative forms of birth control.

The reports of the most recent American and British population panels were released respectively in 1972 and 1973, and they were quite similar. They regarded population growth as aggravating environmental and social problems, but the tone of the reports was far from alarmist. They both subscribed fully to maximizing freedom of choice in connection with reproduction. During the preparation of the U.S. report and since its release fertility in the U.S. has declined sharply, removing much of the immediate concern about population growth. Moreover, the unenthusiastic response of the White House to the report, which was issued at the beginning of the 1972 Presidential campaign, was hardly conducive to development of an official population policy. Probably the only developed country that is still concerned about too much population growth is the Netherlands, with its past history of high fertility, its high density and its dependence on external resources.

Governments in general are not particularly enthusiastic about adopting population policies because of the moral, ethnic or political sensitivities involved. Therefore, unless rates of growth decline further, which of course they may do, there does not seem to be much prospect of further developments in policies concerning population growth in the advanced countries of the world. If any population goal at all is emerging in the developed world, with some exceptions it seems to be in the direction of population stabilization. All the talk about what governments do or do not do about population should not, of course, obscure the fact that the trend of the birth rate has been much more a response of couples to their perception of their own welfare than a result of deliberate government policy.

population size dominance of Asia's population in the world total [*see illustration on page 153*]. Underdeveloped Asia, which has a land mass smaller than Africa, contains almost 55 percent of the world's population. Of the somewhat fewer than 2.9 billion people in all the underdeveloped world some 75 percent live in Asia: 28 percent in China, 33 percent in South and West Asia and 14 percent in Southeast Asia. Latin America's share is 11 percent and Africa's is 14 percent.

The figures on births, deaths and the resulting natural increase, which are the components of population dynamics, also show a broadly similar regional balance. In fact, the current relative magnitudes of absolute population increase in the underdeveloped regions closely match the total population. Therefore growth rates are relatively uniform among the underdeveloped regions. The population of China is an exception: it may be growing at a rate of 1.7 percent per year. The rates for the other four regions, however, fall within the remarkably narrow range of from 2.4 to 2.7 percent per year.

These figures are extraordinarily high, particularly if one considers that they are averages characterizing large continental populations. In spite of imprecisions in the underlying statistics there can be no doubt that the present rates are at or near their all-time high in each region, again with the possible exception of China. The implications of the figures for population trends in the years ahead, however, are not at all clear. Is growth still accelerating? If so, how fast and to what level? Are the rates of increase leveling off or even declining? If a decline is under way or imminent, how rapid is it likely to be?

Unfortunately the present state of knowledge allows no unequivocal answers to these questions, crucial though the answers would be for a realistic assessment of the demographic future of the underdeveloped world and its social and economic prospects. The first steps toward an answer can be made on the relatively firm terrain of descriptive demography. Beyond that attempts at interpretation and prediction lead quickly to more speculative grounds.

A significant step toward understanding growth prospects in the underdeveloped world is the realization that the nearly identical growth rates of the major regions are the result of substantial compensating differences in birth and death rates. For example, in Latin America the number of births per [illegible] in the early 1970's, and the number of deaths per 1,000 population (the crude death rate) was 10, yielding an annual increase of 27 people per 1,000, or 2.7 percent. In Africa the similar growth rate of 2.6 percent resulted from much higher birth and death rates (46 and 20 respectively). Underdeveloped Asia outside China had a growth rate of 2.4 percent, resulting from a birth rate of 39 and a death rate of 15.

Given such contrasts even among the broad continental averages, it is not surprising that the national figures (from which the regional figures are built up) show a much greater variability. Even within the 10 largest countries of the underdeveloped world, which contain more than half of the world's population and more than 70 percent of the population of all underdeveloped countries, birth rates range from a low of 31 per 1,000 to a high of 49. Deaths vary from eight per 1,000 to 25. A broader sample of underdeveloped countries, which still excludes the smallest political units, extends the range of birth rates from the low 20's to about 50 and the range of death rates from five to nearly 30.

Demographers seek to sort out this bewildering variation by means of the conceptual framework called the demographic transition. Niceties apart, the framework rests on two pillars of solid fact. First, mortality in premodern, preindustrial societies was high and so therefore were death rates. Populations that survived must necessarily have maintained high levels of fertility, that is, high birth rates. Second, in advanced industrial societies both mortality and fertility are low, without exception. The demographic transition is the process whereby societies move from the stage of high mortality and high fertility to the stage of low mortality and low fertility. All underdeveloped countries are now in such a transition. The wide differences in their birth and death rates show simply that they have traveled different distances along the route and that the relative timing and speed of their transitions in fertility and mortality are not uniform.

It seems clear that past distributions of birth and death rates for the underdeveloped areas were far more tightly clustered around their mean level than they are today. As recently as two decades ago the birth rates were with few exceptions in the range from 40 to 50 per 1,000. One can surmise that only a half century earlier death rates below 30 per 1,000 must have been rare.

The difference in the time at which a loosening of the pretransition clusters of birth and death rates becomes manifest suggests another generalization that can be made about the demographic transition: The onset of the decline of fertility tends to follow the decline in mortality with a lag. Indeed, the spectacular acceleration of population growth in the modern era is largely a manifestation of the lag. The frequent references to "soaring" birth rates in popular interpretations of contemporary demographic changes in the underdeveloped world have little factual basis and in many instances no basis at all. Rapid population growth is mainly a result of falling death rates unaccompanied by adjustments in birth rates.

The underlying asymmetry in demographic behavior is readily understandable. Longer life is a universally recognized good. Mortality levels therefore closely reflect a society's capacity to control death. As that capacity increases mortality tends to fall.

The age-old attitude toward high fertility was always rather similar to the attitude toward longer life: high fertility was considered a blessing. The attitude may have stemmed from the necessity of coping with low rates of survival, but it was, and is, hardly rooted in that factor alone. Reducing fertility from traditional high levels that are buttressed by customs and social norms is not a process constrained only by what is feasible, as is the case with reducing mortality. Effective methods of fertility control have always been known and available in all societies. Fertility transition implies profound social changes rather than merely a change in technology.

What are the salient features of the transition that is transforming the demographic landscape in the underdeveloped world? Improvements in control over death, with periodic reverses, characterize the entire modern period. The phenomenon is emphasized by the fact that the total population of the underdeveloped countries nearly tripled between 1750 and 1950.

Such growth was much more rapid than was shown in the long-term trend before the era of intensive European contact and colonization. The growth appears to be attributable mainly to gradual (but not universal) improvements in levels of living resulting from improvements in economic organization, agricultural technology and transportation and distribution facilities. Recent

acceleration [illegible] mortality because of an increasing application of advances in the technology of health and environmental sanitation.

Although the impact of mortality on population growth is mediated by the crude death rate, the ratio of deaths to population is a poor index of mortality. The risk of dying is strongly influenced by age. The number of deaths in a population in any year is therefore a function not only of the overall mortality level but also of the age distribution.

To bypass this difficulty by presenting estimates for all ages separately is cumbersome. A more convenient measure of comparative levels of mortality, either over time or among different populations, is the expectation of life at birth. This measure is defined as the number of years newborn children would live on the average if they were subjected during their entire life to the risk of dying at each age as observed in the year for which the index is constructed.

The pitfalls of attempting to compare levels of mortality by means of crude death rates are often anything but negligible. For example, the current death rate in Taiwan is five per 1,000 population and the expectation of life is somewhat less than 70 years. The current death rate in East Germany is 14 per 1,000, even though the expectation of life at birth exceeds 70 years.

As of early in the 1970's the expectation of life in underdeveloped countries was roughly 53 years. The figure represents the population-weighted average of the separate estimates for the more than 140 countries and territories that make up the underdeveloped world. In the developed countries the expectation of life at birth was 71 years, which is close to the current level in the U.S.

Although the overall level of mortality in the underdeveloped countries is high in comparison with the level in the developed countries, it represents an extraordinary achievement by any other standard, most notably in relation to developmental status. It is a level that even in the leading European countries was not reached until the beginning of the 20th century. In the U.S. and much of Western Europe it was reached only during the period between the two world wars, and in the U.S.S.R. it was not reached until after World War II. The speed with which mortality has been reduced has also been much more rapid in the underdeveloped countries than it was in the developed ones.

Thus the historical relation of mortality lev[illegible] developmental status, which was never excessively rigid, has [illegible] developed countries. The application of readily imported health technology provides the major explanation for the shift. It would be incorrect to assume, however, that the fundamental nature of the relation has also been modified. Both the willingness and the ability to apply the technology that will raise life expectancy still tend to reflect achieved levels of development [*see top illustration on opposite page*].

With the caution that prediction is risky, the following propositions that have a strong bearing on the prospects for population growth in the underdeveloped countries appear to be supported by the evidence. (1) Further substantial gains in longevity are likely to be achieved in most countries if per capita gains in consumption continue the upward course that has persisted since World War II. (2) A combination of moderate economic growth with a strong bias toward allocating resources to measures that reduce mortality, including particular attention to increasing the economic well-being of the poorest third of the population, could bring life expectancy in the underdeveloped countries close to 70 years by the end of the century.

The scope for further improvement in mortality is relatively modest in Latin America and in a number of countries elsewhere where fairly low levels of mortality have already been achieved, such as in Taiwan, Sri Lanka, Thailand, South Korea and Malaysia. The growth-generating potential is still high in much of Africa and, most significantly, in many of the countries with the largest populations, including India, Indonesia, Bangladesh, Pakistan, Egypt and probably China. Thus in many countries, including some of the most populous ones, the crest of the population wave may be yet to come, since initial fertility declines are unlikely to be strong enough to compensate for the effects of improving mortality. Where the wave will be ebbing, the deceleration for some time is likely to be held back by the still feasible gains in human survival.

The other crucial element (and most likely the deciding one) in the demographic equation is fertility. In the early 1970's the average birth rate in the underdeveloped world as a whole can be estimated as 38 per 1,000. Of the 37 countries with a population of 10 million or more in 1973 (representing some 90 percent of the total in terms of population size), 10 countries had birth rates below 40 per 1,000; in five of these the [illegible] between 35 and 40. In all underdeveloped countries with birth rates below 40 per 1,000 fertility has been declining, in some cases rapidly. It is possible that a decline is also under way in a number of the 27 countries with birth rates of 40 or more, although the inadequacy of the statistics makes the matter uncertain.

In trying to forecast the trend of fertility in these countries special interest attaches to the underdeveloped countries where a recent onset of fertility decline has been clearly established and where the tempo of the change can be measured with reasonable precision. Four countries among those with a population above 10 million are in this category: Taiwan, Sri Lanka, West Malaysia and Colombia. The pattern of their demographic transition during the past two decades is traced in the accompanying illustration [*opposite page*], together with the pattern in three smaller countries (Mauritius, Costa Rica and Puerto Rico) that are broadly representative of a larger group, including notably Singapore, Barbados, Jamaica and Trinidad and Tobago.

The relative smallness of the population of the underdeveloped countries where substantial fertility declines can be documented and the numerous special economic, geographic and social features that characterize these populations should caution against generalizing from their experience as to the demographic prospects in the rest of the underdeveloped world. In fact, a clear lesson that emerges from an examination of contemporary demographic trends is that past transition experience gives only limited guidance in pinpointing the expected onset and the speed of the decline of birth rates.

This is not to suggest a lack of understanding of what causes such a decline. A significant drop in the birth rate can be explained persuasively by developmental changes that modify human behavior in such a way that the age of marriage tends to rise and the number of children per couple tends to fall. The developmental changes include increased schooling, greater social mobility, urbanization and increased participation of women in the labor force. In such circumstances the perception by couples of the cost and benefits of children may shift.

The behavioral motor force of the demographic transition can be summarized in a single sentence: In demographic matters, as in others, people tend to act in accordance with their in-

terests as they [illegible] interests are and how people see them are to a large extent determined by the objective environment. Nonetheless, the presence of a subjective component in the equation suggests the likelihood of varying fertility responses to broadly similar developmental circumstances, not only among individuals but also among countries. In particular, how changes in objective economic and social circumstances are reflected in the human consciousness may be powerfully affected by "cultural" factors. Thus, for example, what is seen as being "adequate" shelter, education or nutrition for one's children—a judgment that is bound to influence the level of fertility profoundly—is as much in the eye of the beholder as a matter objectively determined, at least above a critical minimum level. Indeed, the evidence shows that the response to similar changes in the pattern of economic opportunities can differ greatly from population to population. Hence there is no reason to expect a close inverse relation between the level of fertility and any particular index of development, such as income per capita, or to assume that attainment of certain identifiable threshold values of development represents a generally valid precondition for achieving low fertility.

These considerations suggest that the potential range of variation in fertility trends among underdeveloped countries is wide. It is therefore of interest to explore the demographic implications of contrasting trends in fertility. At one extreme is the familiar upper-boundary assumption of continued high fertility with mortality approaching the level that has been achieved in the developed countries. The case need not be elaborated here—not necessarily because the assumption is implausible but because the implications of compound-interest growth are clear.

It is more interesting to examine trends that might be generated by exceptionally rapid and far-reaching patterns of transition in fertility. The calculations demonstrate that continued population growth is implied, even if fertility declines rapidly, whenever the demographic conditions resemble the ones in the underdeveloped countries. The conditions include an age distribution skewed toward the young, mortality that is relatively low or declining and high fertility or fertility that may have been declining but only over the past 10 years or so.

A typical example is Costa Rica [*see illustrations on following page*]. [illegible] replacement-level fertility, that is, a level that, if it were maintained, would eventually generate "zero population growth," would not prevent the population from doubling within 50 years. At that time the population would still be growing at a rate of .5 percent per year.

An alternative and equally extreme assumption is that starting from the situation in 1970 no family would have more than two children. Such a fertility regime is drastically below replacement level; in the example illustrated it implies an eventual decrease of 23 percent between generations. Such is the momentum built into the existing age distribution, however, that growth would continue for more than four decades. The population in 2000 would be nearly 40 percent higher than in 1970. Although negative growth would set in by 2015, after extraordinary transformations in the age structure, the population in 2060 would still exceed the level observed in 1970.

Clearly an early stabilization of population through fertility decline, given typical conditions in an underdeveloped country, is an extremely remote possibility. The virtual certainty of continued rapid growth among the underdeveloped countries for many decades suggests that in most such countries a strong social interest should attach to the achievement of an exceptionally early and steep decline in fertility. This is not the place to review the economic arguments that lend force to the suggestion. It is enough to say that the arguments lead to the conclusion that rapid population growth results in a lower per capita income than is associated with lower rates of population growth.

One wonders therefore what the prospects are for an early and rapid decline in fertility in underdeveloped countries. Although a demographer can explain why fertility declines when it does and can specify conditions that are sufficient for fertility to decline, such knowledge does not add up to a useful predictive theory. The answer can therefore be at best only tentative.

Part of the answer is suggested by the likely course of development. Since a rapid growth of population slows down development, a high fertility (other things being equal) will delay the achievement of the objective conditions that make a decline in fertility possible. This relation could create a vicious circle in which poverty and high fertility [illegible] developed countries during the past decades has on the average exceeded the rate of change in population size. If this difference persists (a somewhat optimistic assumption), it cannot fail to eventually create conditions that are more favorable to a decline in fertility. If the demographic response to development is similar to past patterns, however, the rate of progress in most instances will be too low to bring about a rapid completion of the demographic transition.

It is possible that the demographic response will not be the same as it has been in the past because of qualitative differences between contemporary development and past development and because of subjective factors. Decisions leading to lower fertility can be regarded as originating in two types of individual desire. One is to seize opportunities that open up in the process of development. Examples include the drive to acquire new consumer goods (epitomized by the bicycle-motorcycle-automobile sequence), the costs of which tend to outstrip rising incomes; the desire to expand a privately owned enterprise by acquiring capital goods; the desire to provide a better education and upbringing to children already born, and an interest in upward social mobility. The chance of success in such endeavors is often powerfully increased by restricting the size of one's family. The effect is reinforced by the decreasing economic benefit that parents derive from children as development progresses.

A second psychological factor that pulls in the same direction is the pervasive disinclination to accept a lowering of one's accustomed standard of living. Both of these motives played a role in past fertility transitions and now exert a downward influence on fertility in many underdeveloped countries. Moreover, it is likely that the exposure to consumer goods and styles of living that conflict with a large family is more intensive now than it was in the past.

The impact of such factors on fertility can be quite strong, particularly if at the same time the society's institutions allow access to social and occupational mobility, if the income distribution is sufficiently compressed so that in any social stratum imitating and catching up with the consumption patterns prevailing in the next-highest stratum appear to be realistic possibilities, and if existing social arrangements give wide scope to individual initiative in improving one's

economic and social groups and thus bear much of the cost of improvement on those who benefit from it. Much of the rapid decline in fertility that has been documented so far in underdeveloped countries is explained by the fact that the countries involved had the kind of conditions I have described. Such conditions are increasingly present or are appearing in a number of other underdeveloped countries, thus holding out the prospect for a spontaneous and rapid fertility decline. In other countries, however, including probably those containing the majority of the population of the underdeveloped world, development-induced changes in the perceived costs and benefits of children to parents are unlikely to be strong enough to elicit a similar reaction in the foreseeable future. In such instances the grimmer alternative mechanism—resistance to a lowering of absolute levels of living due to adverse economic developments—may still play a catalytic role.

A new and possibly major element affecting demographic prospects is the scope of government activity in shaping economic and social development. In recent years the governments in many underdeveloped countries have introduced policies designed to hasten a decline in fertility. The step is without historical precedent.

The fundamental justification for intervention by a government in the choices that individual couples make on childbearing rests on what can be termed spillover effects, meaning that the consequences of individual decisions on fertility are not fully borne by the people making them but impinge on the interest of others. In such situations it is at least possible that collective action arranged through the government can improve social welfare. Whether such a possibility does indeed exist must be tested through the accepted rules of collective decision making in any given society. As always, a clear diagnosis of a social problem is not enough; the available remedies may be deemed worse than the disease.

Up to now the practice of underdeveloped countries in the field of fertility policy has seemed to reflect both a desire to avoid measures that have high political costs and a lack of effective policy tools that promise to reduce fertility. Accordingly the main line of attack has been the introduction of family-planning programs, which help couples who already want to avoid having more children. Sound arguments exist for supporting the subsidized provision of family-planning services quite apart from the possible contribution of access to modern methods of birth control is an element in social development. The power of family-planning programs to achieve more than limited demographic objectives, however, is questionable. Since people can be expected to find the means to control fertility if they want to, and since without such a desire the availability of inexpensive and effective contraceptive technology is inconsequential, it is unlikely that family planning can do much more than accelerate a process that would occur in any case. Still, in most countries even this limited potential is far from having been exhausted.

In several countries family planning has been combined with another policy, which is often called population education. Apart from providing information, the policy seeks to modify desired family size by persuasion and by inculcating behavioral norms that are more in harmony with the collective interest. If the social costs of such an effort are deemed acceptable, and if the instruments for changing preferences can be perfected, population education may become a powerful device for achieving lower fertility. For the near future, however, its potential seems to be limited except in highly integrated societies with strong and respected leaders.

Beyond family planning and population education is one additional tool of policy with significant potential. It involves the modification of the objective signals that shape parental decisions on childbearing. A superficially appealing approach is to speed up the development process, since "development" does lead to lower fertility. This prescription, however, confuses ends and means. If it were not for dissatisfaction with the progress of the development process itself, the case for government interference with fertility would not arise in the first place. Such interference is a cost rather than an objective that is desirable in its own right.

A more realistic possibility is to rearrange developmental priorities in such a way as to strengthen the features of the socioeconomic fabric that help in reducing fertility. The rearrangement must be sufficient to provide a net positive return for the sacrifice of deviating from otherwise preferred developmental patterns. Two broad approaches can be described.

One strategy is to influence such factors as literacy, infant mortality, income distribution and the status of women, which in turn indirectly influence fertility choices. The obvious attraction of this approach is that it can promote policies that are also desirable on other grounds. Given the poor predictive power of existing fertility theory, however, it is doubtful that indirect effects alone would provide an adequate case for modifying social policies that would be adopted in the absence of the demographic argument.

The other strategy would operate directly on the costs borne and the benefits received by the people who make fertility decisions. The aim would be to eliminate or at least mitigate harmful spillover effects. Just as the system of national states largely decentralizes what is often referred to, rather misleadingly, as the world population problem (nations by and large reap the benefits and bear the costs of their demographic behavior), such a strategy in effect would seek to decentralize the national problem of finding the optimal pattern of fertility behavior to smaller units within the nation. The key element in the solution would require that the units be small enough so that informal decision making and flexible methods of bargaining on the desirable level of fertility would still be feasible. The individual family constitutes a plausible unit, but larger groups, such as village communities, are also possible candidates. If the signals on which such decentralized decisions are based correctly reflect the private and social costs of fertility, the outcome of the decisions could be accepted not only as an expression of individual or small-group preferences with which society has no reason to quarrel but also as being optimal for the society as a whole.

To transfer the burden of fertility to those generating it is, of course, not a costless policy. Nineteenth-century Europe practiced it to a significant degree, but most tendencies of social policy in underdeveloped countries go against the grain of the prescription. (China is an apparent exception, although the case is not well documented.) Nonetheless, if such a policy is combined with measures that soften its harshness but preserve its bite, it may provide the most humane and equitable solution to a problem with which the underdeveloped world should come to grips.

It is difficult to predict the extent to which an effective social technology for controlling population growth will be perfected and employed. As far as Latin America, Africa and the less populous nations of Asia are concerned, the most realistic guess is that they will muddle through a more or less classic (although probably accelerated) process of

fertility transition in which pressures generated by "natural" development reduce fertility, and family-planning programs speed up the process somewhat. The forecast implies that the unprecedented population spurt now being experienced by those countries will continue through the 20th century. By the same token it implies a significant worsening of their long-term welfare prospects in comparison with what would have been possible with a different demographic picture.

It is less certain that such an option is still open to some of the largest countries in the southern half of Asia. There the costs of failing to achieve an early and dramatic reduction of fertility are likely to be prohibitively high. The increasing recognition of that fact may lead in the coming decades to solutions that do not now seem feasible.

Food and Population

The earth and technology can probably provide food for a population of 40 to 50 billion. Increases in food production would help to create the conditions that would stabilize the population at a lower level

by Roger Revelle

Inhabitants of the developed countries tend to forget that the preoccupation of most of mankind is obtaining enough food. The underdeveloped countries are engaged in a desperate race to keep food supplies growing at least as fast as population. In global terms the record of the period from 1951 to 1971 was reasonably successful. World production of cereal grains, the principal staples of the world food supply, more than doubled, whereas the world's population increased by less than 50 percent. Thus cereal supplies per person rose substantially, by about 40 percent, over the 20-year period. The increase was not, however, shared equally by the world's population. More than half of it was absorbed by the richest 30 percent of mankind and less than half was spread unevenly among the poorest 70 percent: the 2.6 billion people of Asia, Africa and Latin America. In these lands between 1953 and 1971 the volume of food produced barely kept ahead of population; it grew by 2.9 percent per year while population increased by 2.6 percent per year, for a net increase in per capita production of .3 percent per year. Even this small gain was inequitably distributed. Latin America fared best with a per capita annual gain of .9 percent. In the non-Communist countries of Asia the annual gain was only .2 percent. And in Africa the volume of food production per capita actually declined by about 1.1 percent over the 18-year period.

The situation deteriorated in 1972 and 1973. In large part because of droughts in India, Africa and elsewhere and poor weather in the U.S.S.R., combined with a rising consumption of beef in the developed countries, world grain reserves have fallen to their lowest levels in two decades, equal to only about a 27-day supply. At the same time the rise in petroleum prices has created a worldwide shortage of nitrogen fertilizers and has lessened the ability of farmers in the underdeveloped countries to pump water for irrigation.

The U.S., the leading exporter of food for the rest of the world, has brought all its idle cropland into production, and unless serious droughts continue it will have larger crops over the next few years than it had in 1972. Most of the surplus, however, will be sold to the other developed countries at prices the underdeveloped ones cannot afford; at the same time food-aid shipments are being reduced. Mankind may be coming closer to a precipice where mass starvation occurs whenever drought or plant disease results in below-average crop production.

There is no simple and dramatic formula for drawing back from the precipice. An obvious, difficult but in the long run absolutely essential step is to reduce rates of population growth. Meanwhile food supplies can be increased through three lines of action: in the short run, creation of a world food bank; in the long run, modernization of agriculture in the underdeveloped countries, and finally a sharp intensification of agricultural and food research.

Six hundred years ago the eminently practical Chinese officially recognized the close connection between food and population. T'ai Tsu, the first Ming emperor, decreed that a sacred Yellow Register be compiled every 10 years, giving the number of households in each district and the number of "mouths" to be fed in each household. A placard, called Hu T'ieh, was posted on the household gate, and the family was obliged to mark on it the number of mouths inside the gate. The census takers then simply counted the mouths recorded on the placards, enabling the emperor's men to estimate the amount of food required for each district.

The relation between population size and the need for food appears obvious: the larger the population is, the larger must be the total quantity of food. The relation is not simple, however. Human beings can survive on much less than an optimum amount of food, and even adequately nourished populations of the same size may use vastly different quantities of edible plant materials. Apparently few peoples anywhere and at any time have allowed themselves to live very long at the Malthusian level of "bare subsistence," if by that term we mean a food supply just sufficient to sustain life, obtained by the maximum work effort the population can exert.

In many respects food is more directly related to the quality of the population than to its size. Unless there is an extreme shortage most adult human beings do not die from an inadequate amount of food, although their vitality and health and their ability to work and play may be greatly diminished. Mortality among undernourished infants and young chil-

"THE THIN KITCHEN" AND "THE FAT KITCHEN," the two engravings made by Pieter Brueghel the Elder on the opposite page, depict the two extremes of human nutrition. The engravings, done by Brueghel in 1563, were accompanied by doggerel in French and Flemish. Freely translated, the verse with *The Thin Kitchen* reads: "Where Thin Man's cook there's meager fare and lots of diet trouble. / Fat kitchen is the place for me; I'm going there on the double." The verse with *The Fat Kitchen* is: "Beat it, Thin Man. Though you are hungry, you are wrong. / This is Fat Kitchen here, and here you don't belong." The prints from which reproductions were made are in the Metropolitan Museum of Art.

dren is relatively high, but the effects on the survivors are more serious for society. Such children are more susceptible to the diseases of childhood and the crippling aftereffects, and both their physical and mental development are stunted.

Some undernourished children are permanently blinded; others are apathetic and hard to educate. Populations that have lived for many generations on meager diets are usually light in weight and small in stature. The average Bengali man weighs 45 kilograms (100 pounds), about the same as a jockey.

As my colleague Rose E. Frisch has shown, nutrition may be related to human reproductive ability. Menarche (the age of first menstruation) is delayed in undernourished girls, and the age of adolescent sterility is prolonged. Severely undernourished women apparently menstruate only irregularly, if at all; undernourished nursing mothers do not menstruate or ovulate for many months after giving birth. Undernourished pregnant women are more likely to suffer a spontaneous abortion than well-nourished ones.

The life expectancy of young children is lowered by the combination of undernutrition and infection that prevails in many underdeveloped countries, whereas in the developed countries the life expectancy of adults is probably reduced by the high content of animal fat in their diet and by overeating.

Human physiological requirements for food are directly related to body weight, sex, age, level of physical activity and ability to absorb the food eaten. Men are heavier than women, and their metabolic rate per kilogram of body weight is higher. Hence they require, on the average, nearly 40 percent more food energy than women. Growing, active children require more food per kilogram of body weight than adults. Although a seven-year-old child weighs only two-fifths as much as an adult, he needs 70 percent as much food. Seventy-year-old men and women require only about 70 percent as much food energy as 20-year-olds. Because healthy adult Bengalis are much smaller than average American men and women, they require only about 75 percent as many kilocalories per day. (The "calorie" of nutritional parlance is actually a kilocalorie.) The U.S. average is 2,700 kilocalories per day. With their high proportion of children the people of Bangladesh would require fewer than 1,800 kilocalories per day, if they were able to absorb as much of their food intake as the average American or European does. The fact is that many people in Bangladesh suffer from damage to the intestinal walls caused by parasites and infection, and as a result they are unable to absorb all the food they eat. Hence their average daily requirement for a normal level of physical activity is probably closer to 2,000 kilocalories.

Future physiological food requirements can be expected to rise faster than population size in the less developed countries, provided that diets can be improved. Better-nourished children will grow faster and larger. (In Japan since World War II the average weight of 15-year-olds has increased by three kilograms per decade.) And as birth rates come down the proportion of children to adults will diminish.

In discussing food we need to distinguish three terms: physiological requirements, demand and supply. Physiological requirements for calories, protein, vitamins and minor nutrients must be taken into account in the computation of the food supplies needed by different countries of the world. These requirements should not, however, be confused with the food demand of a given population, that is, the quality and quantity of the food actually consumed. This demand depends on food prices and on average incomes as well as on the size of the population. If the incomes of the majority rise faster than food prices in low-income countries, where many people are undernourished, the volume of the food demand per person will increase; conversely, if food prices rise faster than incomes, the demand will decrease even to a level where the diet of most poor people does not meet their normal physiological requirements.

The world demand for edible crops and animal products was about 2.6 billion tons in 1970, equal to nearly half the tonnage of all fossil fuels consumed that year and four times the weight of world steel production. The Food and Agriculture Organization of the United Nations (FAO) has estimated that world consumption will rise 40 percent by 1985, to 3.7 billion tons per year. For both years this works out to an average for the world's human population of about two kilograms (4.4 pounds) per person per day. Nearly half of the total tonnage of crops and three-fourths of the energy and protein content is in wheat, rice, maize and other cereal grains. A large fraction of these grains is eaten by domestic animals.

In high-income countries rising incomes or falling prices increase the demand for higher-quality, higher-priced food, although demand for total food calories at the individual level may not rise. The increase in food demand, expressed in money terms, is a small fraction, however, of the rise in incomes. In the U.S., for example, where we spend only about 13 percent of our disposable income on food for household use, a $1 increase in income will result in an additional expenditure on food of less than 13 cents at the supermarket, and the farmer will receive only about four cents more. In India the average person spends between 60 and 90 percent of his income on food, and a one-rupee rise in his income can correspond to an additional .7 rupee for food.

The discrepancy between developed and underdeveloped countries in the fraction of income spent on food reflects Adam Smith's insight that "the rich man consumes no more food than his poor neighbor. In quality, it may be very different, and to select and prepare it may require more labor and art, but in quantity it is very nearly the same. . . . The desire for food is limited in every man by the narrow capacity of the stomach."

In spite of their limited stomachs and low rates of population growth, all the developed countries have managed over the past 20 years to increase their food demands rapidly and substantially, in terms of both food costs and pressures on the volume of world crop production, by changing the character of their diet. With their rapidly rising incomes the Japanese have been eating more beef and less rice; similarly, Europeans are relying much less on cereals and potatoes to fill their stomachs and much more on meat, particularly beef. The consumption of beef per person in the U.S. more than doubled between 1940 and 1972, and total meat consumption per person increased by a third.

Although the average citizen of the developed countries spends a relatively small fraction of his income on food, that is a great deal more in absolute terms than the expenditure of the average Asian, African or Latin American. Compare the U.S. and India, the world's fourth- and second-largest countries in population size. Average household food supplies in the U.S. cost about $600 per person per year, whereas the value of the average Indian's diet is probably less than $45. Two-thirds of the cost of the American diet is for transportation, processing, packaging and marketing. Hence the value at the farm gate is about $200 per capita, still between four and five times the total value of the Indian diet.

For this difference in cost the American obtains about 50 percent more calories and protein and nearly seven times as much fat [*see illustrations on pages 166 and 167*]. He also eats between two and three times the quantity of green vegetables, four times as much fruit, nearly four times as much sugar and syrup but only about 40 percent the weight of cereals. He gets most of his protein and fat from meat (including fish), eggs and milk products, whereas most of the Indian's protein and 40 percent of his fat come from cereals, legumes and nuts. The average Indian's diet just about meets his physiological requirements of 2,100 kilocalories per day, whereas the food going into the average American's household exceeds his energy requirements by 20 percent. A large part of this excess is fat discarded in cooking and on the plate.

In terms of the world's food demand, the most important difference between American and Indian diets is the high proportion of meat, milk and other animal products in the American diet. Cattle, sheep and hogs require about seven calories of plant products for each calorie of protein and fat in meat. Chickens and cows eat about 4.5 calories of plant material per calorie contained in the eggs and milk they produce. Most of the plant calories eaten by domestic animals in the U.S. could also be eaten by human beings, so that Americans actually use, directly or indirectly, close to 10,000 kilocalories of humanly edible plant products per person per day. The average Indian feeds his domestic animals largely on humanly inedible materials, and this, together with his low intake of meat, eggs and milk, means that he uses about 2,300 kilocalories of edible plant calories per day. In terms of the farm value of plant calories on the world market the cost per calorie of the average American diet is about the same as that of the average Indian diet.

In most underdeveloped countries there is a marked disparity in incomes between a few relatively well-off people and the great mass of the poor. Yet the poor, because of their numbers, consume most of the food. A rise in per capita incomes, resulting largely from an increase in the incomes of the well-to-do, will bring little increase in food demand for the country as a whole.

Between 1953 and 1971 the average volume of food consumption per capita in Africa, Latin America and the non-Communist countries of Asia, according to FAO estimates based on food production in those countries, grew by .3 percent per year. In the same period the average per capita incomes for the underdeveloped world (again omitting the Communist countries of Asia) rose 1.85 percent per year, ranging from 2.4 percent in Latin America to 1.8 percent in Asia and 1.5 percent in Africa. Only about 16 percent of the average increase in per capita income was reflected in the increased volume of per capita food consumption estimated by the FAO, less than would be expected considering that the peoples of these countries typically spend 50 percent or more of their income on food.

Part of the discrepancy can be explained by uncertainties in the data and by the neglect of food imports in the FAO estimates of the volume of food consumed. Three other possible explanations could account for the remainder. First, there was probably some change from lower-priced to higher-priced foods in the diet of the people in the underdeveloped countries as their per capita income rose. Second, even without a change in diet the real cost per ton of food production may have risen. Finally, the rise in per capita income may have been unevenly distributed, with a small group of relatively well-off people getting most of it. The already well-off would not be expected to spend much of their additional income on food. The last explanation receives some support from the estimate by the FAO that food consumption per person rose two or three times as fast in the Asian Communist countries, which presumably have a narrower range of incomes than the market-economy countries of Asia.

The total world food supply over a period of years depends largely on the crops and animal products produced by the world's farmers and to a much lesser extent on the world fish catch, but the supply in any individual country in a given year depends both on its agricultural and fish production and on the food reserves saved from previous years, together with its imports or exports of food. No country and no region in the modern world, except possibly some of the interior areas of New Guinea, is self-sufficient in food.

As we have seen, the worldwide doubling of cereal-grain production between 1951 and 1971 was divided nearly equally between the 1.1 billion people of the developed countries (Europe, North America, Oceania, the U.S.S.R. and Japan) and the 2.6 billion people of the underdeveloped countries (Asia, Africa and Latin America). Both groups of countries in 1970 produced approximately 600 million tons of cereals, but since the underdeveloped countries had a much larger population, their production per person was only about 40 percent of that in the developed countries. By the same token because the rate of population growth was more than twice as high in the underdeveloped countries the rate of increase of cereal production per person was far smaller.

There is a feedback relationship between food supply and demand in most of the underdeveloped countries. Since their economies are overwhelmingly agricultural, an increase in agricultural production that benefits the mass of the rural population will increase their real incomes and hence their demand for food.

The small production per head of staple food crops in the underdeveloped countries condemns most people to a monotonous, low-quality diet, consisting mainly of cereal grains or tubers and other starchy roots. For the poorest 20 percent of the population the diet falls below the physiological requirement for a normally active, healthy person. Low levels of production also cause food demand to tend to outrun supply in the underdeveloped countries. They are unable to produce much of a surplus of supply over demand in good years, which could be used as a reserve for lean years. As a result they are extremely vulnerable to fluctuations in weather conditions. That vulnerability is increased by the high sensitivity of traditional agriculture to the weather.

During most of the past two decades the underdeveloped countries have been able to tide themselves over bad years, and to stretch their supplies in good years, by drawing from the surplus stocks of some of the developed countries, particularly the U.S. Before World War II the underdeveloped countries as a whole were net exporters of cereals, but they have since become net importers. Between 1949 and 1972 their gross imports of cereals rose from 12.4 million tons to 36 million. Before 1972 between a third and a half of this tonnage was obtained under U.S. and other food-aid programs. Although food aid has been justifiably criticized because it tended to hold back badly needed agricultural investments and incentives to farmers, there can be no doubt that it contributed substantially to the increase in per capita food sup-

plies in the underdeveloped countries, and thus to the improved [illegible] tions that were reflected in the dramatic rise in life expectancy of between five and 10 years per decade in many countries. Then in 1972 there was a crisis, and its effects still persist.

Food demand in the poor countries tends to be relatively insensitive to food prices because the need for food is the most urgent of all human needs. When food prices rise, poor families must forgo other wants in order to obtain food. At the same time if food reserves are low, the supply cannot be increased much during any given crop year by raising prices to provide greater incentives to the farmers. In the developed countries the same short-run constraints operate on supply; moreover, food expenditures are such a small part of total income that rising prices may have a relatively small effect on demand. Hence a slight decrease in world food supplies is likely to cause a sharp rise in prices.

Exactly this process operated during the crop year of 1972–1973. Droughts and poor weather conditions caused a drop in total world cereal production for the first time in more than 20 years. The decline from the 1971–1972 crop year was actually only 35 million tons, or less than 3 percent. Demand, however, continued to increase, partly because of the inexorably continuing rise in the world population and partly because of the continuing increase in meat consumption, particularly beef consumption in Europe, the U.S.S.R. and Japan. The world production of cereals, currently totaling about 1.2 billion tons, has to increase between 25 and 30 million tons per year if the rising demand is to be met. Thus the real shortfall in 1972–1973 was nearly 60 million tons, or roughly 5 percent. World cereal reserves have been drawn down to a dangerously low level, a supply of less than 30 days in the spring of 1974, and cereal prices rose steeply in 1972 and 1973. By December, 1973, the price of Thai rice was nearly four times the 1971 price and the price of wheat for export was more than three times as high. With the drawing down of reserves through export sales to the U.S.S.R., Japan and Western Europe, food-aid shipments from the U.S. and other rich countries were sharply reduced. The unprecedentedly high prices have been particularly hard on the poorer classes of the underdeveloped countries. Since 1973 the poor countries have been struck another heavy blow. The drastic increase in world oil prices not only has raised the cost of pumping ground water for irrigation but also has [illegible] which was already in short supply.

Many people have suggested that in order to avoid a repetition of the 1972–1973 situation there should be created an internationally managed world food bank, from which supplies in the underdeveloped countries could be augmented during years of poor crop production due to bad weather, insect plagues or widespread plant disease. Such a world food reserve would need to be operated carefully to avoid the undesirable effects of food aid in holding back agricultural improvements in the underdeveloped countries and to keep from unduly depressing farm prices. Without attempting to specify the characteristics of a world food bank in detail, it is possible to point out that such a bank should have several components: stores of wheat and other cereals and of soybeans and other legumes; stores of fertilizers to enable crop production to expand quickly; reserves of land that can be put under the plow in emergencies; a store of information and technology that can be used to increase crop yields, and stores of crop genes to make it possible for seeds of new varieties to be quickly multiplied when the old varieties are stricken by pests or plant disease.

To even out the fluctuations in world production of cereals and legumes the capacity of the world food bank would have to be high, perhaps of the order of 5 percent of the average yearly production, worth at present prices between $10 billion and $15 billion. For example, from 1962 to 1966 there was a run of poor years in the world production of wheat, rice and maize, giving rise to a cumulative departure from the production trend line of 80 million tons by 1966, even though the total production of these major cereals rose from 790 million to 885 million tons over the five-year period.

Establishing a well-managed world food bank during the next three or four years could be helpful to farmers in the principal exporting countries. With normal weather the U.S. can expect a succession of bumper crops, with a resulting heavy downward pressure on prices. The prospect of wild price gyrations is made grimmer by the possibility of a recession in Europe and Japan resulting from inflated petroleum prices.

In the long run the solutions for the underdeveloped countries must be twofold: as fast a reduction as possible in their rates of population growth and a [illegible] cultural production. If a rapid and con[illegible] production can be directed toward a marked improvement in the lives of the poor rural masses, one of the essential conditions for lowering human fertility will be attained.

The physical possibilities for increasing agricultural production are great, in terms both of natural resources and of agricultural technology. When Thomas Malthus announced in 1798 his famous "Principle of Population" (that human populations were limited by the food supply because they grew "geometrically" whereas food production could be increased only "arithmetically"), he thought that the resources available for agriculture were primarily land, water and human and animal labor. For most of the world that is still true. For human beings in the developed countries, however, agriculture and the procurement of food have decade by decade become progressively smaller components of the total economic activity. Today household food expenditures in the U.S. take less than 13 percent of disposable personal income in spite of an extravagant diet, and of this small amount the farmer receives only about a third. The transformation has been brought about mainly by the large-scale application in agriculture of two resources of which Malthus was hardly aware: mechanical energy from fossil fuels, and scientific and technical knowledge.

Mechanical energy is used, for example, in manufacturing and operating tractors and other farm equipment, making and applying fertilizers, pesticides and other farm chemicals, pumping water for irrigation and transporting the inputs and products of agriculture to and from the farm. The applications of science and technology to agriculture are equally diverse, from establishing the physics and chemistry of water and soils and the genetics, physiology and pathology of crop plants and domestic animals to the practical control of insects, the engineering design of irrigation and drainage systems and the economic analysis of the alternative uses of agricultural resources.

To underscore the vast changes brought about by the new agriculture, let us compare the actual cultivated area on the earth with the area of farmland that would be needed to feed the present population if modern agricultural technology were used everywhere. The average harvest of corn in Iowa is about 100 bushels per acre, or 6.4 tons per hectare, corresponding to 60,000 kilocalories per day: enough to feed 24

people at a level of 2,500 kilocalories per day per person. With a present world population of 3.8 billion people, 158 million hectares would be required, assuming only one crop per year. Yet for the world as a whole at the present time 1.4 billion hectares are cultivated. This works out to one hectare of farmland for every 2.7 living people.

Several reasons explain why the actual cultivated land per person is nearly 10 times the hypothetical minimum. To begin with, the land actually harvested during any particular year is only about half to two-thirds of the total cultivated land. The remainder is temporarily left fallow or used as meadowland for mowing or pastures or is not cropped for some other reason. When chemical fertilizers are not applied, much farmland must lie fallow for a year or more to recover its fertility. About 10 percent of the cropped area is devoted to raising nonfood crops: cotton, tobacco, rubber, coffee, tea, jute and so on. Another large fraction is needed to produce food for livestock and poultry. Some of the livestock are used as draft animals on farms. The products from the rest, including butter, eggs, milk and meat, are eaten by human beings. From a human standpoint domestic animals are only from 14 to 23 percent efficient, that is, they use from four to seven times as much food energy as the energy contained in their edible products. In addition from 10 to 20 percent of the food crops are destroyed by pests, and a small percentage is required for seed. The principal reason, however, 1.4 billion hectares of land now have to be cultivated is the low level of agricultural technology in most of the world. Instead of the more than six metric tons of cereal grain per cropped hectare that is obtained in high-technology farming, the average Indian or Pakistani farmer produces only about a ton of wheat or rice.

Because of the dispersed nature of solar energy and the low efficiency of photosynthetic energy conversion (about .4 percent in terms of human food energy) arable land remains a primary resource for agriculture. Large areas of the earth's surface are not now cultivated but could be if farmers and the necessary capital for development were available. The potentially arable area is limited by climate (the land must be free of frost during the growing season), the physical characteristics of the land surface and the water supply. Water must be available during the growing season in amounts approximately equal to or greater than the evaporation from the soil and the transpiration from plants.

In a 1967 report, *The World Food Problem*, President Johnson's Science Advisory Committee estimated that the world area of potentially arable land is 3.2 billion hectares. That is 24 percent of the land area of the earth, about 2.3 times the currently cultivated area and more than three times the area actually harvested in any given year. Unfortunately 500 million hectares of this total are in the humid Tropics, where precipitation exceeds evaporation throughout the year and no technology is currently available for intensive crop production (except in a few regions such as Java, where there are very deep volcanic soils). Crops could be grown on another 300 million hectares if water were available for irrigation. On the other hand, the potential gross cropped area, that is, the sum of potentially arable areas multiplied by the number of crops that with a four-month growing season could be raised annually, is considerably larger than the net area. In many regions multiple cropping would require irrigation development.

In an attempt to estimate the limits set by water supply on the potential net and gross cropped areas I have examined the proportion of the flow of the world's rivers that could be used for irrigation. Only a small fraction of river runoff is now diverted to the world's farms, even though irrigation agriculture represents, even today, man's principal deliberate use of water. Less than 4 percent of the total river flow is employed to irrigate 160 million hectares, or about 1 percent of the land area of the earth.

The potential for irrigation development is thus very large, but it is limited by the uneven distribution of river runoff between the different continents and within different climatic zones on each continent. About a third of the total runoff comes from South America, which has less than 15 percent of the earth's land area, whereas Africa, which has 23 percent of the land, yields only 12 percent of the runoff. Runoff from Southwest Asia, North Africa, Mexico, the southwestern U.S., temperate South America and Australia is less than 5 percent of the total, yet these regions have 25 percent of the land area.

As a result of the uneven distribution of runoff, only slightly more than 30 percent of the land that is potentially arable with irrigation can actually be irrigated, and the potential increase of gross cropped area through irrigation development is limited to 1.1 billion hectares. Omitting the humid tropics and taking account of the insufficiency of water where it is needed, the total potentially arable land is reduced to 2.5 billion hectares (the present 1.4 billion plus 1.1 billion) and the potential gross cropped area reaches just under 4.1 billion hectares.

If 10 percent of this potential gross cropped area were set aside to grow fibers and other nonfood products, and if technology and purchased inputs of production (irrigation water, fertilizer, high-yielding seeds, plant protection, farm tools, farm machinery and farm practices based on scientific knowledge) equivalent to those used in Iowa corn farming were applied to the remainder, a diet based on 4,000 to 5,000 kilocalories of edible plant material could be provided for between 38 and 48 billion people, between 10 and 13 times the present population of the earth.

Much of the potentially arable land is of poor quality, and in general any major extension of the currently cultivated area, even for subsistence agriculture, would require a huge capital investment: of the order of between $500 and $1,000 per hectare. A more serious obstacle is the uneven distribution of potentially arable land with respect to the distribution of population. Seventy percent of the world's people live in Asia and Europe, where nearly all the potentially arable land is already cultivated; the remaining land in Asia could be brought under the plow only at the expense of large-scale irrigation development. The potential for increasing the net cultivated area is also relatively small in the U.S.S.R. Most of the uncultivated but potentially arable land lies in the more sparsely populated continents [*see illustration on these two pages*].

Human diets in Asia are barely adequate today. If the Asian peoples are to have sufficient food in the future, it will be necessary to increase yields on currently cultivated land, that is, the weight of each crop per hectare. It will also be necessary wherever possible to grow two or three crops per year on each cultivated hectare. Such double or triple cropping will usually call for extensive irrigation development.

The largest areas of potentially arable land are in Africa and South America, which, except for the relatively small continents of Europe and Australia, have the smallest cultivated acreage. Outside the humid Tropics 630 million hectares with sufficient water remain uncultivated. The limiting factors in agricultural development on these continents are not natural resources but economic, institutional and sociopolitical constraints. In addition to the potentially arable land in

Africa and South America. Roughly 300 million uncultivated arable hectares exist in North America and Australia.

The principal merit of the above calculations is their demonstration that the quantity of potentially arable land on the earth is so much larger than the area actually cultivated today, and the possibilities for increasing agricultural production on currently cultivated lands are so great, that the area of the earth's surface that will be devoted to agriculture in the future is chiefly an economic and social variable rather than a physical one.

In the less developed countries the basic requirement for a continuing advance in agricultural technology is the creation of better conditions for market agriculture as contrasted with subsistence agriculture, because high agricultural technology depends on the ability of the farmers to purchase, and of society to produce, many inputs from outside the farm. The modernization of agriculture depends on overall social and economic development in the poor countries as well as on the development and dissemination of new knowledge to the farmers. This will require much higher levels of industrialization and more effective public and private institutions.

Social and economic development that brings an increase in per capita income and a more equitable income distribution is probably also a necessary condition for a continuing reduction of rates of population growth, and ultimately for a stationary world population. Here we are faced with a paradox: attainment of the earth's maximum carrying capacity for human beings would require a high level of agricultural technology, which in turn calls for a high level of social and economic development. Such development, however, would be likely to lead to a cessation of population growth long before the maximum carrying capacity is reached.

The underdeveloped countries are confronted with a more immediate circularity. In terms of both employment and production, agriculture is an overwhelmingly important component of their economy; agricultural modernization is essential for their overall economic development because it will create a consumer surplus that can be saved and invested in other economic sectors. At the same time, however, agricultural modernization depends on overall economic development because it requires many inputs from outside agriculture and a large and growing market for agricultural products.

Ecological damage caused by human agricultural activities is much more likely to occur through the expansion of traditional agriculture into unsuitable or easily damaged environments than through agricultural modernization, which from many points of view improves the environment (for example by the reduction of erosion). Nevertheless, agricultural modernization, particularly the use of wide-spectrum pesticides and excessive quantities of fertilizer and the elimination of potentially valuable components of plant and animal gene pools, has also been environmentally destructive. One of the kinds of knowledge that needs to be sought through research is the knowledge needed to minimize the deterioration of the environment.

The new consciousness of man's energy needs has generated alarm about the intensive use of fossil-fuel energy in modern agriculture. Some people have even called for a return to the old methods, when grinding human labor, assisted by the toil of horses and oxen, was the main form of energy used in farming. Apart from the manifest impossibility of maintaining traditional agricultural practices if the growing populations of Asia are to be able to feed themselves, this point of view has little basis in the realities of energy utilization.

John S. Steinhart of the University of Wisconsin and Carol E. Steinhart have recently pointed out in *Science* that American agriculture, in spite of its energy-intensive character, accounts for only about 3 percent of the total U.S. energy consumption. Our entire elaborate food system, including all processing, manufacture of food containers, transportation and distribution of foodstuffs, plus commercial and home refrigeration and cooking, requires less than 13 percent of the energy used in the U.S.

David Pimentel, Walter Lynn and their colleagues at Cornell University have estimated the quantity of fossil-fuel energy used in U.S. corn production, not only the energy applied directly in farming but also that used in manufacturing farm tools, machinery and chemical fertilizers, and in transportation to and from the farms. They find that the solar energy captured in the grains of corn, let alone that captured in the leaves, stalks and cobs, is two and a half times the total energy used by farmers, including their own labor. Corn farming can be thought of as a kind of breeder reactor in which much more energy-containing material is produced than is consumed. One of the reasons for the relatively small use of energy in U.S. corn production is that [illegible] of the area planted to corn is irrigated. Irrigation, particularly ground-water irrigation, is highly energy-intensive, but, as we have seen, it is essential in order to realize the full potential for multiple cropping in many underdeveloped countries.

Using the data compiled by Pimentel and Lynn, I have estimated the energy that would be required in a modernized, irrigated agriculture and food-processing system in India [*see illustration on page 165*]. Energy for the construction and operation of flour and sugar mills and cold-storage plants is included but not energy for cooking and food preparation in households. (Fuel for household purposes is a serious problem in India. The burning of cow dung, although an efficient method of energy conservation, does not provide an adequate supply of fuel.) My calculations show that the food energy obtained would be about twice the mechanical energy utilized, in spite of the large amount of energy used to pump ground water for irrigation.

For the present average Indian diet of 2,150 kilocalories per day, 410,000 kilocalories of fossil-fuel energy per person would be required each year, equivalent to 55 kilograms of coal, costing, at 1974 prices, $2.50. That is about a fourth of the per capita use of fossil-fuel energy in India today. For a future diet of 3,700 kilocalories of primary plant materials and a population of 1.2 billion people, instead of the present 580 million the total energy requirement for agriculture would be the equivalent of 95 kilograms of coal per person, or a total of 114 million tons per year. Estimated reserves of fossil fuels in India are between 100 and 1,000 tons per person. Hence if India relied on her own fuel reserves, enough energy would be available for a modernized agriculture for several hundred years. As I have pointed out, however, agricultural modernization depends on overall social and economic development, and as this development proceeds total energy utilization can be expected to increase manyfold above the present level. Such an increase could not be sustained for very long with existing reserves of fossil fuels. Just as in the currently developed countries, the future welfare of India must depend on the development of nuclear and solar energy.

Since 1951 India's farmers have increased their production of food grains (mainly rice, wheat, corn, millet, sorghum, peanuts, beans and peas) by 86 percent and per capita production by 16 percent (.6 percent per year). They ac- [illegible] impressive gains both

by the traditional method that farmers have always followed—bringing more land under the plow—and by the beginning of a modernization of Indian agriculture. Over the two decades the area of India's cultivated land increased by about 20 percent, and the area on which more than one crop was grown per year and the area under irrigation both approximately doubled. The use of chemical fertilizers was increased thirtyfold. As a result yields per hectare of rice and wheat for all India rose by 60 percent and 83 percent respectively, and the total production of rice increased by 105 percent and of wheat by 340 percent. The total harvest of corn increased by 265 percent. The increase in these highly valued grains was much greater than that for millet, sorghum and the various legumes, which are less desired as foods. By expanding its own harvests India was able to reduce its imports of food grains by some 60 percent. At today's prices this represents a saving in foreign exchange of some $800 million per year, much more than the annual costs of additional fertilizers and irrigation.

Both the need and the possibilities exist for a sharp acceleration in the rate of modernization of Indian agriculture. The Irrigation Commission of the Government of India has estimated that the irrigated area of 43 million gross cropped hectares in 1973–1974 could just about be doubled during the next 30 years, at a total cost of roughly $14 billion. This would be less than 1 percent of India's current gross national product.

If this projected irrigation development can be combined with an optimum utilization of fertilizers, with crop varieties that are highly responsive to fertilizers (the "miracle," or high-yield, varieties), with control of plant diseases and pests and with development of the knowledge, skill and human potential of Indian farmers, the problem of India's food supply could recede into the background for the foreseeable future. Assuming, for example, a population of 1.2 billion during the first half of the 21st century and yields equivalent to six tons of food grains and 500 kilograms of cotton per gross cropped hectare of irrigated land (yields of this magnitude have already been obtained in Egypt and some other underdeveloped countries), the total energy in edible crops would be the equivalent of about 3,700 kilocalories per person per day. This would allow a per capita consumption of about 25 grams of animal protein from milk, eggs and poultry and an average dietary energy content of 2,400 kilocalories. The socioeconomic changes resulting from such agricultural development could set in motion powerful forces for reductions in human fertility, and population growth could gradually be brought to a halt.

A more serious situation can be projected for Bangladesh. Careful studies by the World Bank and the Harvard Center for Population Studies have shown that with a total capital investment of nearly $2 billion annual rice and wheat production available for human consumption could be raised to about 20 million tons by 1993. Since rice and wheat constitute 82 percent of the energy content of the diet, 20 million tons would be barely enough to meet the average physiological requirement of the more than 130 million people anticipated at that time, meaning that the diet of half of the people would be below these requirements. Further modernization of agriculture might allow an eventual doubling to 40 million tons, but self-sufficiency in food production could not be long sustained in the face of continuing population growth. Thus Bangladesh is confronted with an urgent and potentially tragic problem. Both agricultural and industrial development for exports to pay for food will be necessary, possibly combined with out-migration on a large scale.

Much world concern has recently been focused on the Sahelian zone, the belt of semiarid steppe and brush-grass savanna that extends across Africa south of the Sahara. This belt is becoming narrowed on its northern side by the steady march of windblown sands, and its use by human beings and their cattle is limited on the south by the tsetse fly. A large fraction of the population of some 25 million are pastoral nomads; most of the remainder live on a meager subsistence agriculture. Human population densities are low, yet after several years of drought severe food deficiencies have become widespread. This is in spite of the fact that the possibilities for agricultural land and water development are great.

The problems here are in many ways opposite to those of India. Levels of living and the potentials for development are not constrained by the pressure of populations on natural resources but by the lack of human and technical resources and of capital for investment. Social, political and economic considerations all point toward the necessity of a rapid development of intensive irrigation agriculture, which could improve the condition of life and raise the aspirations of the people. Otherwise population growth will almost certainly keep up with increasing food supplies, and the inevitable result would be a more desperate situation than the one that now exists. In the early stages capital and technical resources will have to be provided by the world community, particularly the developed countries, but the commitment of these countries to the underdeveloped ones has been diminishing for a decade.

Agricultural modernization in the underdeveloped countries is one of the great challenges facing mankind. For future human welfare such modernization must proceed much more rapidly than population growth, so that standards of living can be raised and opportunities for improvements in the conditions of life can be increased. If it does not take place quickly, it may not be possible at all. The developed countries have an essential role to play in the first stages of this modernization because they possess a large share of mankind's present ability to gain the needed knowledge through research.