

Life of the individual bear ultimately results in death, and the annual loss of individuals from the population makes possible annual recruitment through birth of new members, ~~to the population~~. The number of ^{those that} ~~proceed~~ will survive and live to maturity depends on the carrying capacity of their environment. When a population temporarily exceeds the carrying capacity, ~~of the~~ environmental resistance factors become more effective and some largely dormant become active. Some of these are self-regulating mechanisms, the bear gizzly killing its own young being an example. When a reverse process affects a population ^{of most animals} and numbers decline drastically, regulating mechanisms tend to compensate, ~~and~~. The number of young produced increases - more calves are born, litter and egg clutch sizes increase. But an animal that throughout much of its existence has had no enemies and thus has not been faced with sudden and drastic population ^{reductions} ~~declines~~ may not be able to cope with the population decline, particularly if it ~~has~~ also has a low reproductive rate as do gizzlies. The greatly reduced Yellowstone gizzly population will most certainly take a long time to return to its former numbers. A continuation of misinformed management, hunting, poaching and other causes of mortality along with continued low-reproduction may result in a continuing decline eventually fatal to the ~~rest of~~ gizzly population of the Yellowstone ecosystem just as it has been fatal to many other such gizzly populations in the not too distant past.

Male grizzly No. 202 was radiotracked for two consecutive years during the summer and fall. As a yearling he was instrumented and radio-monitored for 56 days in 1965. During that time he established a 69.9 km² (27 mi²) home range, that encompassed Canyon Village, and a winter den on the steep slopes of Yellowstone Canyon. In spring when he emerged from winter sleep he swam the river and travelled along the north rim of the canyon to the Canyon Village campground. He was then retrapped, reinstrumented and as a two-year old he was radio-monitored for 118 days during 1966. The canyon campground and surrounding areas became a part of his home range, but he gave no serious trouble until fall when he began visiting nearby construction camps. Here he received food handouts and learned to associate man with food. During 1966 this two year old grizzly established a home range of 323.7 km² (125 mi²) which included Canyon Village campground as the center of his activity and a den site in the canyon some 300 feet from his previous den. When No. 202 again emerged from winter sleep he returned to his old haunts near the Canyon campground. Although he was not an aggressive bear and had inflicted no injury and caused little or no property damage he had been conditioned by food handouts. In this way he had lost his normal respect for man and thus had become a potential menace to park visitors. He was shot as a precautionary measure to prevent possible human injury at the age of 3.5 years.

Grizzly No. 39, the mother of instrumented grizzly No. 158, extended her home range in 1968 to include Lake Campground and the Bridge Bay-developed area. During 1968-69 she was captured five times at the Bridge Bay incinerator and twice in adjacent developed areas. In both years she was probably attracted there by odors from the incinerator. The increase in this grizzly's home range coincided with the reduction in available food at the Trout Creek dump. (Craighead, J.J. and F.C. Craighead, Jr. 1971).

Known age bear No. 6 was instrumented at the age of 5.5 years so we could monitor and track her during the mating season. In a 19-day period she ranged over 12 square miles (31 km²).

We instrumented female No. 101 in 1967 at the age of 10.5 years in order to obtain more information on early season mating. Female No. 187 was observed to mate at 4.5 years of age and was instrumented for a 65-day period so we could observe her mating activities and attempt to learn the time interval between mating and implantation of blastocysts (Craighead, J.J. and F.C. Craighead, Jr. 1969). During 1967 home ranges were determined for females No. 187 and 101. Number 187 was a 4.5 yearold female known to have mated and thought to be pregnant. She was tracked for 65 days and located or sighted on 54 of these. The area of her range was 39.8 square miles. Her prehibernation movements were closely monitored and her den site located. She made two trips to her den before finally returning to "hibernate."

Female No. 101 was instrumented twice in 1967; the first time on September 5th and the second time on October 19th. She was tracked for 49 days and located and sighted on 36. The area of her range was determined to be 43.1 square miles. Female 101 had one yearling of her own and two adopted ones, the offspring of sow No. 40. Throughout the summer this family travelled, foraged and slept together. Both of the adopted yearlings nursed the female. The sow however, hibernated with only her single offspring. The two adopted yearlings denned within the home range of their mother, sow No. 40 but their dens were not located. We disturbed 101 at her den in the course of tracking her and this caused her to abandon the den and select a new site. At the first site she dug a den, gathered a large pile of boughs and was starting to prepare a bough bed. She left the den and dug another within a period of about a week. It was located about one half mile from the first den. We monitored her activities closely during this time and moved in to locate her second den in November just before she entered it November 19 for the winter. At our close approach she growled threateningly but neither ran away nor charged. We took her warning seriously and moved off without further disturbing her.

The trapping, marking, tatooing, instrumenting and tracking by radio were all techniques employed to gather information on the population of grizzlies. This also includes such techniques as the removal of the fourth pre-molar for aging or the making of plaster casts of the feet and jaws. When a ~~xxxxxxxxxxxxxxxxxxxx~~ sufficient amount of data was recorded, it was tabulated and tentatively analyzed. Each year we were obtaining a better understanding of the grizzly bear population. Our census of the bear population was a sample of the entire ecosystem population and as pointed out earlier consisted of a 77% sample. The information obtained from this sample would be applicable to the entire population of bears, even though some individuals making up this total, we had never observed or handled. In 1968, after 9 years of data gathering, we were able to work out with some degree of certainty the population parameters that we had set as one goal of our study.

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Nutrition, Development, and Population Growth

by Alan Berg

Editor's Comment: In the modern world, the observable and measurable tragedy of famine has claimed universal attention and inspired international action. As a consequence, many developing nations have made remarkable gains in agricultural production during the past decade. But less attention has been given to the quality of the food produced and its distribution. The insidious effects of malnutrition are less dramatically evident than those of famine. Only recently has persistent research into the nature and dimensions of these effects on human and economic development succeeded in capturing the interest of policy makers in poor nations.

A growing body of evidence points to a strong relationship between poor nutrition and the quality of human populations. A host of problems—high infant and child mortality rates (and their decided influence on birth rates), the incidence and complications of disease, poor maternal health, low worker productivity, school dropouts, lagging economic development, and so on—are associated with malnutrition.

These relationships are discussed here, as are some of the avenues open to planners for eradicating certain nutritional deficiencies plaguing people in low-income countries. For example, the use of new and fortified foods could reduce nutritional deficiencies at far lower costs than those incurred by the human debilitation caused by malnutrition. Infant nutrition could be vastly improved by reversing the steep decline in breast feeding that has deprived countless children of nourishment during their most vulnerable period. An added advantage of lactation is the protection against pregnancy it offers women in poor nations who are largely unaware of other forms of contraception.

Improved nutrition could have other important demographic consequences. In low-income countries large families represent security for parents who, as a guarantee against the loss of those who die, have many children. But adequate nutrition can substantially decrease infant and child mortality and thereby reduce the number of pregnancies required to assure the desired number of surviving children. This in turn may provide a motivation for using family planning services that does not now exist among many peoples of the world.

The discussion of nutrition presented in this *Bulletin* has been drawn from an important new book, *The Nutrition Factor: Its Role in National Development*, written by Alan Berg, with portions by Robert J. Muscat. It is reprinted with the permission of the Brookings Institution, which published the book in 1973. In addition to the excerpts given in the *Bulletin*, Mr. Berg's study contains discussions of other issues, such as nutrition education, public feeding programs, and the role of industry.

Mr. Berg prepared *The Nutrition Factor* as a senior fellow at Brookings and as a Belding Scholar of the Foundation for Child Development, which provided financial support for the project. He is now Deputy Director for Nutrition in the Population and Nutrition Projects Department of the World Bank.

A forthcoming *Bulletin* on growing pressures on world food resources, written by Lester Brown, will be a companion to this issue. 

"I think it could be plausibly argued," wrote George Orwell in *The Road to Wigan Pier*, "that changes of diet are more important than changes of dynasty or even of religion."¹ As with other things Orwellian, people are starting to take heed. In policy-making quarters in several parts of the world, nutrition has begun to strike a sensitive chord. Disturbing research findings about the effects of malnutrition on childhood death rates, on the frequency and severity of mental illness, on physical growth, on productivity, and on mental development have stirred concern. For years it has been assumed that, given educational opportunities and other environmental advantages, a child had every reason to be as bright, imaginative, and productive as other children of his age. Now it is being suggested that the child behind the empty-eyed face commonly seen in poor countries may be backward.

The greater interest of policy makers in nutrition also reflects their growing disenchantment with accepted economic development dogma. To large portions of the populations of low-income countries, the so-called Development Decade of the 1960s did not fulfill its promise. Rising expectations are giving way to rising frustrations. New solutions are being sought.

At the same time, nutrition is becoming a more relevant policy issue—and remedial action more feasible—as countries are relieved of the pressure of an inadequate food supply. Several countries whose food shortages in the mid-1960s prompted U.S. Congressional hearings on the apparent inevitability of famine in the 1970s have achieved or are approaching self-sufficiency in cereal grain production. For many of them, growing enough food is no longer the most immediate concern. In fact, there is or soon will be broadened choice of land use. Should a country use the land to plant

crops for export, to increase production of domestically needed industrial raw materials, or to raise more nutritious foods to improve the local diets?

The answer is neither simple nor obvious, for malnutrition is not dramatically visible. Unlike famine, which attracts national and international attention—and usually prompts substantial response—most malnutrition is unobtrusive. The day-in, day-out erosion of health it causes may reach epidemic proportions—malnutrition has been identified as the world's number-one health problem and is associated with more deaths and disease than the occasional famines—but it lacks drama.

The most telling reason for the neglect of the problem of malnutrition may be the isolation of the power structure from its effects. Malnutrition does not raise the pervasive concern of the politically and socially vocal classes that an ailment like malaria, which knows no class bounds, arouses. Nor has it the urgency of a contagious disease—like smallpox.

The Malnourished

For most developing countries, then, with limited resources and a plethora of needs, the question is why should governments finance major programs to combat malnutrition? To planners in the developing countries, the answer is not at all clear. The magnitude of the malnutrition problem can best be appreciated by considering the amount of child mortality, the relationship of malnutrition to that mortality, and the extent of malnutrition among the survivors.

Available child mortality data are probably understated; in many instances children who are born today and die tomorrow are not recorded. In parts of Ghana, for example, the

Table 1. Malnutrition as Primary or Associated Cause in Deaths of Children under Five, Selected Areas, 1971

Area	Percent of deaths in which malnutrition is associated cause				Percent of deaths caused by malnutrition		
	Measles	Diarrhea	Other infective or parasitic cause	Respiratory cause	Other cause	Primary cause	Associated cause
Argentina							
San Juan Province							
San Juan				8	33	3	37
Suburban				35	33	9	39
Rural				39	30	8	39
Chaco Province							
Resistencia				50	47	7	57
Rural				25	20	3	48
Brazil							
Recife				51	34	6	60
São Paulo				33	41	6	45
Ribeirão Preto area							
Ribeirão Preto				56	54	2	67
Franca (small town)				46	28	9	49
Colombia							
Cali				40	35	16	40
Cartagena				36	33	15	44
Medellin				29	45	11	51
Jamaica: Kingston				24	31	6	32
Bolivia: La Paz				25	11	4	41
Mexico: Monterrey				51	34	4	48
Chile: Santiago				31	38	6	39
El Salvador							
San Salvador area				29	29	9	49
San Salvador				40	24	14	44
Rural				36	33	8	46
Average of all areas							

Source: Pan American Health Organization, *Inter-American Investigation of Mortality in Childhood, First year of investigation, Provisional Report* (Washington, 1971).

n.a.—Not Available.

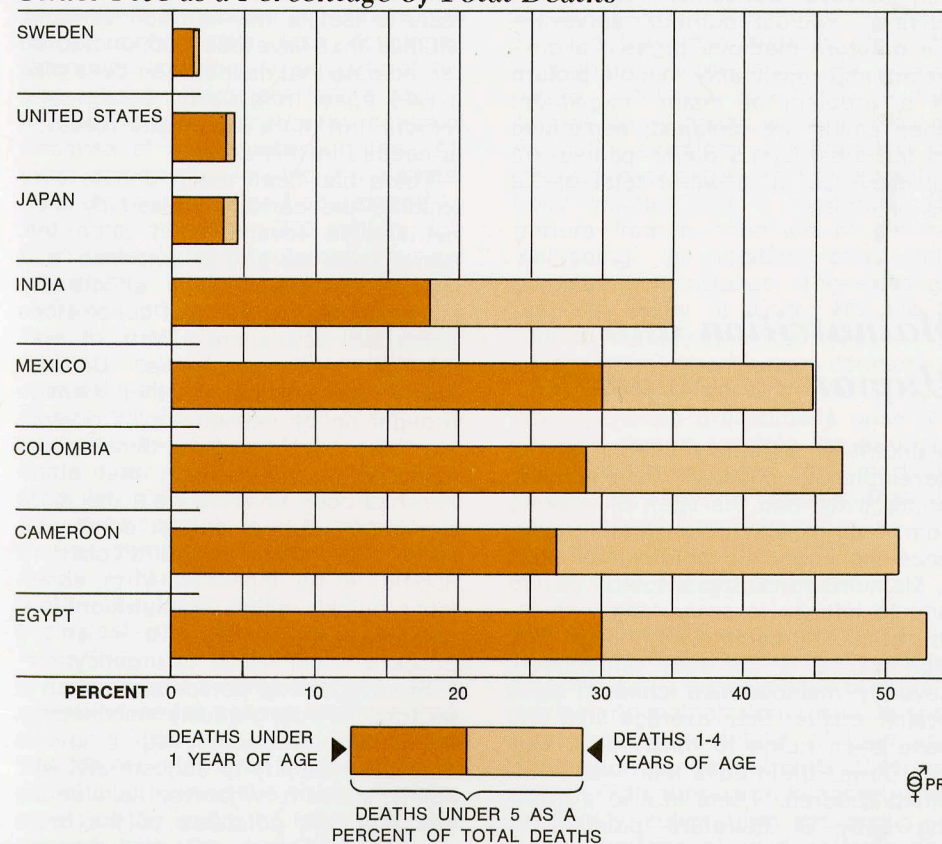
naming of a child is postponed eight days; if it does not survive that long, it is not counted as a birth. Generally, the more poverty stricken the area, the higher the death rate, and the higher the death rate, the poorer the available records.

Nonetheless, figures still show that child mortality in developing countries is of staggering proportions. There is little dispute that malnutrition is the biggest single contributor to child mortality in the developing countries. In parts of Latin America, where the making and selling of mini-caskets are common sights, malnutrition has been

identified as the primary or associated cause in 57 percent of all deaths of one-to-four-year-olds; it is an important factor in more than half of infant deaths and a contributor to the immaturity responsible for half to three-quarters of deaths in the first month of life.

Malnutrition causes otherwise minor childhood diseases to become killers. For example, respiratory and gastrointestinal infections in Nicaragua are responsible for 15.3 percent of all deaths; the comparable figure in North America is only 0.4 percent. In Guatemala, 500 times as many preschool-

Fig. 1. Deaths to Infants Under One Year of Age and to Children Under Five as a Percentage of Total Deaths



Source: United Nations, *Demographic Yearbook, 1971* (New York, 1972).

aged children die of diarrheal diseases as in the United States. The death rate from measles, an especially virulent killer when accompanied by malnutrition, was more than a thousand times greater in Guatemala than in the United States in 1965.

Deaths are measurable. The toll among the survivors is less dramatic and less visible. Yet, more than two-thirds of the 800 million children now growing up in developing countries are expected to encounter sickness or disabling diseases either brought on or aggravated by protein-calorie malnutrition. Whatever the technique for measuring the extent of malnutrition—food balance sheets, food consumption surveys, consumer expenditure surveys, medical nutrition surveys—the different methods present a consistent and reasonably reliable picture of a problem of major magnitude: when adults are included, something on the order of 1.5 billion people are affected—out of a world total of 3.8 billion.

Malnutrition and Human Development

Malnutrition adversely affects mental development, physical development, productivity, and the span of working years—all of which significantly influence the economic potential of man.

Malnutrition during the fetal period and in infancy is associated with intellectual impairment. Although the significance is not fully understood, severely malnourished children have brains smaller than average size and have been found to have 15–20 percent fewer brain cells than well-nourished children. There is also a growing body of literature pointing to malnutrition as a cause of abnormal

behavior as well as evidence that suggests that abnormalities in the young may produce chromosomal abnormalities that may persist.

That malnutrition inhibits a child's ability to cope with the requirements of daily existence is apparent. However, whether early inflicted damage leaves a permanent scar is a complex question that is just beginning to be answered. Studies in several countries indicate that once-malnourished youngsters perform less well on mental tests in later years than their well-nourished counterparts. Other unmeasured (perhaps unmeasurable) deprivations—such as lack of stimulus and maternal warmth to the institutionalized child—make it difficult in human tests to isolate the nutrition variable. Studies that have been conducted so far indicate that malnutrition does play a role apart from social background factors, but more systematic research is needed in this area.

There has been much debate over whether the damage caused by malnutrition is reversible in later life. Some point to strong evidence that malnutrition permanently affects the mind. Others believe that conclusions about the permanent effects of malnutrition seem premature. Unfortunately, the question whether damage brought on by malnutrition is reversible has so dominated the thinking and research on malnutrition that attention has been diverted from the more significant public policy considerations. For many public officials, it appears to be imperative to do something quickly about malnutrition if it is irretrievably limiting; if it isn't it poses a lesser sense of urgency.

From a policy perspective, such a posture is dangerously misleading. Malnutrition interferes with a child's motivation, ability to concentrate, and ability to learn, whatever its ultimate effect on the condition of the brain itself. Learning time is lost during the

most critical periods of learning. A malnourished child is listless, lacking in curiosity, and unresponsive to maternal and other stimulation. Even if he were not so, the maternal stimulation he requires for proper development frequently is unavailable; the mother herself is often a victim of nutritionally induced lethargy.

Physical development

While heredity is the key to the ultimate size a youngster can attain, nutrition largely determines how close he will get to his genetic potential. Studies in Japan, Taiwan, and other countries witnessing nutritional improvement in recent years all point to remarkable increases in stature. In many economically less developed countries, however, large parts of the populations clearly are falling significantly short of their genetic potential because of inadequate nutrition. Almost universally, low-income populations have a smaller body size than the norm; more than 300 million children suffer "grossly retarded physical growth."²

Other than for jobs that require more than average physical prowess, physical size in itself generally is not economically significant. But the shortfall in size may be related to a shortfall in performance. Small stature often reflects other disabilities. Experts contend that a six-year-old with the physical development of a three-year-old can be compared in learning and behavior with neither age group; "he is another being altogether, with his own biological and behavioral characteristics."³

The nutrition problems of poor countries, so far as food is concerned, are both quantitative and qualitative. The former refer to an inadequate supply of food to meet the energy requirements of the body; the latter are concerned with the body's needs for

particular nutrients that are required for growth, repair, and preservation of the body and bodily functions.

Man is subject to the laws of thermodynamics; he must absorb energy to produce energy. Men living on 1,800 calories a day have been shown to lose 30 percent of their muscle strength and 15 percent of their precision of movement. Speed, coordination, and many behavioral characteristics also have been altered. Improvements in clearly inadequate diets have often been found to bring increases in work output and work attendance. The inadequately fed apparently make compensating adjustments in the energy they expend to preserve the internal processes. For the adult worker, this means, in effect, living a less than average life as a less than average man. He adjusts for his nutritional shortfall by a mixture of slowly paced work, savings on muscular exertion, opportunities for innovation or extra effort forgone, low body weight, and a moderate departure from a condition of general well-being. In addition, other deficiencies—for instance, iron—also affect his ability to work. His life is further complicated by illness that proper nourishment would counteract. Though life expectancy in a poor country jumps dramatically once the average person survives the perils of young childhood, early adult mortality is still substantially greater than in industrialized countries.

Nutritional deficiencies

The most severe and widespread nutritional deficiencies, especially among children, are a consequence of protein and calorie malnutrition, resulting both from inadequate intake of food and malabsorption of nutrients that are eaten. With serious deficiencies, children may suffer from marasmus—a gross shortage of both calories and

Table 2. Male Life Expectancy at Specified Ages in Selected Countries

Country	Expected years remaining at age					
	0	1	5	10	15	20
Cameroon	34	40	42	41	38	35
Central African Republic	33	40	41	38	n.a.	31
Chad	29	34	34	31	n.a.	26
Colombia	44	50	52	48	44	40
Egypt	52	56	61	57	52	48
Gabon	25	34	38	36	n.a.	29
Guinea	26	33	35	32	n.a.	29
India	42	48	49	45	41	37
Japan	69	69	66	61	55	51
Mexico	61	62	60	56	52	47
Nigeria	37	45	49	47	43	39
Sweden	72	72	68	63	58	53
Taiwan	66	67	64	59	54	49
United States	67	67	64	59	54	49

Source: UN, *Demographic Yearbook*, 1968 and 1970. Data are for various years in the 1950s and 1960s.
n.a.—Not available.

protein—or kwashiorkor—primarily a shortage of protein.

Inadequacies of other nutrients, either directly or in combination with protein or calorie shortages, are well-discussed in medical texts, but limited data suggest that many vitamin deficiency diseases are no longer prevalent. In most countries once-serious problems such as rickets, scurvy, and beriberi may have become of secondary importance. The two prominent exceptions are vitamin A deficiency and iron-deficiency anemia. The sickness and sluggishness—and the effect of fatigue on physical performance—brought on by anemia are so common in poorer societies that the condition is often accepted as the norm.

Pregnant and lactating women are especially vulnerable to nutritional anemia. In Latin American countries, 29–63 percent of expectant mothers have been found to be anemic. In India, 66–80 percent are anemic, and 10 percent of maternal deaths in child-

birth are the result of nutritional anemias.

Vitamin A deficiency commonly afflicts up to half the children in developing countries. The deficiency affects growth, skin condition, the severity of other nutritionally related illnesses, and vision. Severe vitamin A deprivation can lead to blindness and is the major cause of blindness in low-income countries.

Nutrition and the National Economy

The mathematically precise economic growth models that have been in vogue since the 1940s seldom take explicit account of the notion of investment in human beings. Increases in tomorrow's income are assumed to result primarily from today's additions to material capital, and since con-

sumption displaces capital investment, it becomes an enemy of growth, not a handmaiden. Consumption in the form of educational services, clothing, and eating of course have an instrumental impact on productivity, but since the effects of such consumption are difficult to identify, all growth in income is imputed to those more easily measurable factors included in the models. Expenditures on health and nutrition are also classified as consumption and thus fail to show up as factors affecting national growth.

Recently, however, the concept of capital has been extended to human beings. Development of the new theory was prompted by the discovery that "increases in national output have been large compared with the increases in land, man-hours, and physical reproducible capital. Investment in human capital is probably the major explanation for this difference."⁴ A significant part of the economic growth in the United States and Western Europe, for example, has been attributed to education, and any residual growth to "knowledge."

In similar attempts to begin to measure economic returns to health investment, the cost of preventing a death is compared with the worker's future income, had he lived. Or the investment in human capital—the health, food, clothing, housing, education, and other expenditures necessary to enable a person to develop his particular skills—is measured against his loss through death any time prior to retirement. Those costs can also be measured against debility, where death is not a factor. Similar comparisons can be made of the benefits to be gained from expenditures on nutrition.

Savings on medical costs

One measure of the benefits of a nutrition program is in the medical costs saved through reduced demand for

medical services. In Caribbean hospitals, 20–45 percent of the pediatric beds are filled by nutrition cases; in India, 15 percent; in Guatemala, 80 percent. Nearly half a million hospital inpatients from 37 developing countries were officially registered for malnutrition in 1968. At an average cost of \$7.50 a day for 90 days for each case, costs for treating malnutrition are on the order of \$340 million a year to the 37 countries. If treatment were provided to the approximately 10 million preschool-aged children who need it, annual costs would be on the order of \$6.8 billion. However, the number of children requiring such treatment to avoid severe (third degree) protein-calorie malnutrition is 20 times the number of medical facility cots available in developing countries for children for all diseases.

Reducing productivity losses

Another potentially large nutrition benefit for developing countries is the reduction in productivity losses caused by debility in the labor force. The interaction of malnutrition with much prevailing illness makes it difficult to pin down the exact contribution of each factor to productivity losses. Nonetheless, the caloric shortfalls among workers in developing countries are almost always very substantial, often as high as 50 percent.

Productivity is also affected by the reduction in working years resulting from early death. For the majority of developing countries, increases in the life expectancy of adults would add years to the working lives (rather than the retirement years) of most adults. In countries where life expectancy at 10 or 20 is particularly short, the added working years would be those when healthy adults would be at the peak of their powers and earning capacity.

Restoring a worker to good health, of course, adds nothing to national production if no job exists for him. The apparent slow growth of employment opportunities compared with the growth of the labor force in poor countries is a common source of skepticism that better health and nutrition will bring economic benefits, particularly in rural agricultural areas. Yet, in such areas in low-income countries, labor is more commonly in short supply than in surplus during harvest and other periods of intense activity. Do farm workers try to feed themselves seasonally to higher capacity, like draft animals? In fact, can they do so during the weeks preceding harvest, when cash income is at the lowest annual point and grain prices are at their peak? What happens to the productivity of workers who undergo alternating periods of well-being and malnourishment? Many functions impaired by a worker's malnourishment cannot be satisfactorily corrected by added hands.

Productivity is of course more than a function of human energy, of numbers of workers. Energy loss is a limited basis for calculating the effect of malnutrition on national production. As development proceeds, human energy is replaced by machine energy; human quality becomes more important than sheer physical capacity.

Other economic benefits

Nutrition programs promise a number of economic benefits in addition to the direct productivity benefits:

- ☐ As the incidence of communicable diseases among the adequately nourished is lowered, the exposure of others to these diseases will be reduced.
- ☐ The increased income of well-nourished workers should improve the living standards of their dependents, thereby raising both their cur-

rent consumption and their future productivity.

- ☐ Housewives, whose activities are not measured in a market economy, should, when better nourished, improve performance of a number of economically important functions, not least of which is the quality of care for the young.
- ☐ Returns may be raised on other investments closely related to human well-being, particularly education. At present, the efficiency of educational systems in low-income countries may be reduced by as much as 50 percent by the dropout and repeater rates to which malnutrition contributes heavily.

Benefits compared with costs

Even where opportunities for returns to better nutrition appear to be significant, the costs must be weighed. Will the nutrition expenditure be less than the value of the expected increases in production? How will it compare with returns to alternative investments?

Productivity payoffs from nutrition investment can be anticipated for workers employed in machine-paced occupations in modern manufacturing sectors, students for whom malnutrition limits the potential joint returns from education and health expenditures, and small farmers facing the more exacting demands of new agricultural technologies. The widest and most lasting impact, however, probably would come from providing adequate nutrition to mothers in the last trimester of pregnancy—the critical period for fetal growth—and to children six months through two or three years of age (most of the needs before six months can be met through breast feeding). The greatest physiological need and greatest growth occur in the early years; 80 percent of eventual brain weight, for example, is reached by the age of two. During this time

children require, relative to body weight, two and one-half times as much protein as adults.

It would be hard to find a more favorable investment opportunity than the avoidance of blindness caused by vitamin A deficiency. Poverty-stricken societies where such blindness is considerable have few facilities for training the blind for productive occupations. The upkeep of the blind, minimal as it is, represents a total burden to their families or the society. Assuming that the average blind person could be sustained at a subsistence cost as low as \$25 a year, the cost is 1,250 times the annual ingredient cost of the vitamin A needed for prevention. The average blind person need only be in position—if sight loss were avoided—to produce a modest fraction of his annual consumption for the investment in his sight to yield an enormous return.

Similar returns can be made from investments to prevent what are in some places common cases of irreversible cretinism and deaf-mutism linked to endemic goiter. In parts of Bolivia, for example, 40–50 percent of the population is goitrous and 5–10 percent of these suffer from cretinism and deaf-mutism. The cost of the iodate to prevent goiter (and the equipment necessary to add the nutrient to salt) is one-sixth of a cent a year per person covered.

Many of the links between diet, performance potential, and economic returns are poorly understood and may remain so, given the complexities of human development and behavior. Little is known, for example, about the relative damage caused by different degrees of malnutrition at different ages and of varying durations. The major benchmark provided by medical science is the concept of “minimum daily requirements” of specified nutrients. Any sustained diet below the minimum daily requirement implies

damage, especially in environments where widespread diarrhea and other ailments lead to heavy nutrient losses. Although it is known that the extent of damage increases as the level of nutritional deprivation falls—as a child moves from first to third degree malnutrition—the shape of the curve relating deprivation to loss of physical, motor, and mental development, and to the severity of nutrition-related diseases, is unknown. The threshold beyond which the extent of loss becomes serious cannot be defined, nor can the degree of mental or physical shortfall or other resulting damage that separates the serious from the inconsequential be calculated.

Although it may never be possible to separate the mass of the world's malnourished children into neat groups whose potential performance can be forecast from specific investments in varying nutritional supplements, a clear line can be drawn between those who will live and the significant number of those who will die of malnutrition or related causes. Before children born today in developing countries reach their fifth birthdays, approximately 75 million youngsters will die of malnourishment and associated illnesses. The known numbers of those whose lives will be marked by illnesses that seriously strike the malnourished are so great, and the effects of malnutrition on educational and productive capacity so apparent, that investment in nutrition programs can almost be undertaken as an act of faith.

Beyond standard economic benefits

For all their economic privation, the poor families of the world have the potential for enjoying a wide range of noneconomic goods—nature, love, friends, good talk at the coffee or tea stall, the joy of children. These enjoyments, independent of economic sta-

tus, include some of the major sources of satisfaction in life. But those who are apathetic and physically drained by nutritional anemia or debilitated by the seemingly constant bouts with nutritionally related diarrhea cannot really savor these satisfactions.

For societies whose prevailing philosophy places a premium on egalitarianism, the intellectual loss that is caused by malnutrition may be a barrier to social mobility. Adequate mental development, hence adequate nutrition, would seem to be a prerequisite to other programs of mobility that are being developed as a matter of social policy. If a child lacks curiosity and mental energy—to say nothing of the possibility of mental capacity—the other opportunities are not significant. Moreover, widespread malnutrition threatens the loss to society of potentially outstanding individuals. Since the origin of so many superior individuals in the middle and upper classes is a result of opportunity rather than genetic potential, it seems appropriate to ask how many potentially superior minds are lost because of malnutrition. Considering how very thin in most countries is the leadership elite on whom rests the burden of the nation's success or failure, such losses would seem to inhibit the chances for economic development.

Economic Growth, Income, and Nutrition

In the development business, the most commonly heard answer to the question of how to provide better diets to children in poor societies is "economic growth." With economic growth and related increased incomes, nutrition problems, according to this view, will solve themselves. Money, of

course, does affect diet—the poorest fed children are usually found in families with the lowest incomes. In developing countries, where the poor spend a high proportion of their incomes on food (in south India, the poorest families spend 80 percent of their budgets on food, the affluent only 45 percent), more money generally means a better diet. As the poor enjoy some increase in income, they usually devote a big fraction of that increase to additional food expenditures.

Income also establishes a pattern for what foods are purchased with the additional money. The poor spend most of it on food grains, the rich much less so. The allocation for cereals declines and that for milk products increases as families move into the middle-income levels. Also, the higher the income, the larger is the percentage of the increase spent on fruits, vegetables, and other variety food items.

Thus, income is a major determinant of diet quantity and quality. Yet, while it is clear that these beneficial relationships between income and nutrition—reinforced by the beneficial effects of rising incomes on improved health and other family circumstances that interact with nutritional status—hold almost universally over broad ranges of increases in income, it is equally clear that incomes rise slowly for the poor, and that even increased purchasing power often cannot overcome certain food habits and practices that stand in the way of effective nutritional improvement, especially for small children.

There are many exceptions to the commonly accepted rules. In fact, the theory that national economic growth leads to better nutrition rests on a series of often questionable assumptions:

- ☐ A national increase in per capita income means an increase large and rapid enough in the income of

Table 3. Allocation of Income for Food Expenditure, Selected Countries, Mid-1960s

Country	Per capita GNP, in dollars ^a	Percent of expenditures allocated to food	Percent of increment of expenditures allocated to food	Animal protein as percent of total protein
Ghana	170	64	76	17
Ceylon	180	56	79	18
Honduras	260	47	40	27
Malaysia	330	49	37	30
Sweden	2,620	32	20	69
United States	3,980	23	20	72

Sources: Expenditures data from UN, *Yearbook of National Accounts Statistics, 1967* (1968); protein data from Food and Agriculture Organization, *Production Yearbook, 1970* (1971).

^a Gross national products are for 1971.

the poor to be of nutritional significance.

- ☐ Increased income of the poor leads to an immediate and automatic increase in the amount the family spends on food.
- ☐ Increases in food expenditures by the poor family lead to an improvement in nutrition.
- ☐ Improved nutrition in the family means an improvement for the nutritionally vulnerable members of that family.

Inadequacy of income increments

For nutritional planning, the role of income and dietary improvement within a society must be judged in relation to specific target populations and viewed in the context of their base incomes, income trends, and existing diets. The important question is how much dietary improvement will flow "automatically" to a nutritionally needy population from likely changes in their incomes over a given period of time.

For many of the nutritionally needy, incomes are not rising or are barely rising at all. From 1960 to 1970, per capita incomes in countries representing two-thirds of the world's population grew only 1.5 percent yearly. And this was average. In some countries,

the increments in income were distributed in such a way that the poorer segments of the population received even less than the average share. In Brazil, the poorest 40 percent of the population saw their share of national income decline during the period by 20 percent. In Mexico, the income share of the poorest 40 percent fell from 14 percent in 1950 to 11 percent in 1969; the already low share of the poorest 20 percent of the population dropped by a third—to 4 percent of the national income. In short, the nutritionally needy portions of the population often have not benefited from their country's income growth, and in some cases, their living standards may even have deteriorated.

Even when income increases at an average rate at the lower levels, improvements come slowly. A composite of 220 surveys of Indian diets, coupled with national economic projections, indicates that unless a new nutrition strategy is adopted and implemented, many of the present generation of Indians will never be able to afford an adequate diet. Per capita disposable income must reach \$4 to \$5 a month to support an acceptable diet, but 60–70 percent of India's urban dwellers, and even more of the rural population fall below this line. Even on the optimistic assumption of a 3 percent an-

nual per capita real income rise, it would take about 25 years before the lowest third of India's population could afford a minimum diet.

Nonfood expenditures and nonnutritious food

Even for those now or soon to be realizing an increased income, more money will not automatically be translated into a larger expenditure for food. The traditionally accepted principle that bigger and better diet is a function of increased income undoubtedly applies over time and over broad increases in income and living standards. However, the broad data on food expenditures may at times be misleading. When income increases are modest and start from a low base, there may be transitional periods of inverse correlation between income and nutrition. For example, when a subsistence farmer switches from growing a variety of foods for his family's own consumption to cultivating a crop for the market, such items as ballpoint pens and transistor radios compete, for the first time, with what had been largely a fixed food income.

Even when expenditures for food are increased, which is commonly the case, additional income does not always lead to improved diet. People spending more for food may eat more, but not necessarily better. In South Asia the common shift with the first increment of income is from sorghum or millet to rice, then from home-pounded rice to the convenience of commercially polished rice; the shifts are aesthetically pleasing but nutritionally costly. In western India a statistically significant drop in protein intake has been discerned as incomes rise and cereal diets are "upgraded."

Aesthetic pleasure and social prestige appear to be more important instigators of change in food habits than the level of vitamin A or the level of

iron; white corn replaces the more nutritious yellow, white bread the *tortilla*; coffee is taken instead of the corn-based *atole*, tea instead of buttermilk. As consumption of manufactured foods—especially sugar-containing foods—increases, meat and fruit are pushed out of the diet. The deleterious effect in urban slums of soft drinks is legend.

Increased income and the nutritionally vulnerable

Even if better-quality food does come into a household, there is no assurance it will reach those in the family who most need improved nutrition—the young child, the pregnant woman, or the nursing mother.

Surveys in Central America, Colombia, Ghana, India, Ivory Coast, Nigeria, and Tunisia show that even when income levels allow older family members to have satisfactory diets, children's diets are commonly 20–30 percent inadequate. This is especially true of the infant; parents often do not recognize the importance of supplementing breast milk at the appropriate age.

In many cases, nutritious foods are withheld from children for fear of adverse consequences. In a Peruvian fishing village, where adult consumption of fish protein is high, fish is not fed to children because parents fear it will make them ill. In parts of Malaysia and Indonesia fish is forbidden to children because it is believed to cause worms, bad eyes, or skin disease. Elsewhere, protein-rich beans and lentils are frequently not fed to children because of concern for flatulence they produce.

Similarly, the introduction of additional food into a household is no assurance that the additional nutritional needs of an expectant mother will be met. The notion of a pregnant woman

eating for two is a Western concept; in most Asian countries, in fact, women consciously undereat during pregnancy, with the objective of a small baby and an easy delivery.

Neither are the extra food needs of the nursing mother guaranteed by increased family food purchases. In some countries, women consciously attempt to eat less after bearing a child. A study of Malays found that many new mothers had severely restricted diets for 40 days following delivery; fruits and vegetables were forbidden. In Indonesia, many women take less food after childbirth to regain their shape. In some Asian countries, many mothers believe that a diet containing animal proteins makes breast milk toxic to the baby. All this suggests that there is no guarantee that increased food intake by a family benefits the three most nutritionally vulnerable groups.

Increased income is not, of itself, a sufficient condition for adequate nutrition, particularly in cases where food beliefs and practices deleteriously affect the nutritional status of the young. Explicit steps such as the establishment of special food distribution mechanisms and supportive measures in education will be required to rein-

force the dietary benefits from higher income. Moreover, in some instances, direct methods to improve diets can be effectively employed in the absence of increased income.

Nutritional Effects of Agricultural Advances

Increased attention to agricultural production is often pointed to in development circles as the key to better nutrition. Clearly, agriculture has a strong influence on a nation's nutritional status. But the exact nature of that influence is not clear. Seldom do agricultural policies flow from specifically stated and analyzed nutrition objectives. Rather, the goals of agricultural production are to reduce dependence on foreign suppliers for major staples, expand exports, produce raw materials for industrial goods, and provide consumers with adequate food supplies that will maintain stable prices and avoid pressures on industrial wages and prices. The supply of com-

Table 4. Sources of Protein in Food Supplies of Selected Countries, Late 1960s

Country	Protein/ capita /day (grams)	Source of protein (percent)							
		Cereals	Starchy roots, plantains	Pulses, nuts, seeds	Fruits, veg.	Meat, poultry	Eggs	Fish	Milk, milk products
Brazil	63	28	6	30	2	18	2	2	11
India	48	65	1	20	1	1	*	1	9
Pakistan	54	70	1	7	2	3	*	2	14
Ghana	43	42	32	7	1	5	*	10	2
Kenya	68	52	5	22	1	12	*	2	6
United States	97	16	4	2	4	39	6	3	24
World	n.a.	50	5	13	3	13	2	3	11

Source: Based on food balance sheets, Food and Agriculture Organization, *Production Yearbook*, 1970. FAO data are for various years between 1964 and 1969. Percentages may not add to 100 because of rounding.

* Less than 0.5 percent.

n.a.—Not available.

modities produced in pursuit of such worthwhile economic goals can affect the nutritional status of needy groups in a variety of ways—ranging from highly beneficial to perverse.

Currently, economically less developed countries typically depend heavily on cereals for their major nutrients. Several nations obtain from cereals more than half of both their calories and protein. Cereals are prominent suppliers of protein not because they are rich in it, but because they are consumed in such enormous proportions compared to other foods. For the same reason they are a major source of iron in the diets of many people in the low-income countries. Pulses are a prominent secondary source for protein, while the traditional protein products—meat, poultry, eggs, fish, and dairy items—account for only a minor portion of the protein in the diets of developing countries. For low-income members of the population, staple crops usually constitute a higher than average portion of the diet.

Impact of the Green Revolution

Given the dominance of cereals in providing the major nutrients, the recent remarkable advances in cereal production, especially in South and Southeast Asia, have important nutritional implications. (Fortunately, the so-called Green Revolution first centered on countries in greatest food need.) West Pakistan's 1971 wheat production was up 76 percent from its 1961–65 average, Latin American corn production up more than 50 percent, Indonesian rice production up a third. The Indian wheat crop of 1971 doubled its 12-million-ton record of six years earlier.

The key to the dramatic turnabout was the development and spread of new high-yielding seeds of wheat and rice and of the technologies necessary to service them. The new seeds, along

with fertilizer, irrigation, and pesticides, provide greater yield per harvest, often doubling traditional output per acre. They also permit two, and sometimes three (often varied), crops a year where formerly there was one. These achievements have taken place on only a small portion of the land devoted to cereal crops. Although significant problems must be overcome for the full potential of the new technologies to be felt, the prospects for cereal production expansion in many countries are much more promising than they were in the mid-1960s.

The nutrient composition of the new seed varieties probably is basically the same as that of traditional varieties. Apparently, the protein level may vary sharply between regions and change from year to year, like wine, depending on growing conditions. The increased yields mean not only more calories but also more protein, vitamins, and minerals.

Thus, a successful policy for increasing the supply of cereal staples can be a powerful tool for nutritional betterment. But a successful production strategy may not, of itself, assure an improvement in the nutritional levels of those in need. As the supply of staples rises and their prices fall off, the real incomes of those who buy the staples will rise, enabling them to buy more staples, as well as other foods, with the same amount of money. While the effect of such a process is clear for the consumer, it is less clear for small producers of the staples. The impact of production policies can vary considerably, depending on the nature of the policies, the social and economic structures of the rural society, and whether the producer is a large or small commercial farmer, a tenant or owner, a subsistence farmer or a landless laborer.

In some areas, the principal beneficiaries of profits from the new high-yielding seed varieties have been

larger farmers; their profit margin makes grain production remain attractive even when supplies rise more rapidly than demand and farmers' wholesale prices are allowed to fall. But the small farmer without irrigation whose output and costs change little may find both his income and his nutritional level reduced. His marketable crop now earns lower returns. If he sells only the surplus after his needs have been met, his cereal consumption may not be affected; but his purchases of other goods—including foodstuffs he does not produce himself—will decline, with possibly adverse impact on his family's nutrition.

The small farmer's ability to adopt the miracle seed technologies depends on such factors as his access to credit, the effort the government's extension service makes to reach and communicate with the poorer cultivators, and the tenurial arrangements that determine the tenant farmer's risks and potential returns from investing in small-scale irrigation or other inputs, and from borrowing to make such investments.

In subsistence economies, where scope for exchange is limited by commodity and by geography, a family's income and its own production are virtually the same thing. Low income and inadequate supply are merely different names for the same localized problem of low productivity, and a supply policy that helps such farmers increase food output helps directly to alleviate nutritional deficits. Similarly, programs to help monetized small farmers raise a "back yard" of vegetables, poultry and so on, can conceivably contribute directly to the family's nutrition (although in practice such programs have fallen short of expectations).

For these and other reasons, what might appear to be simply technical questions of a production supply policy turn out to have important effects

on who participates in the development process, who has access to productive inputs, to whose income the increased supply accrues, and thus the impact on the nutritionally deficient groups. In the near euphoria surrounding the Green Revolution such considerations have often been slighted.

Declining pulse availability

The Green Revolution has had a number of indirect consequences. One of the most disturbing is the decline in the production of food legumes or pulses, the family of food crops that includes peas, lentils, beans, chick-peas, mung beans, pigeon peas, and broad beans.

In most low-income countries, pulses are widely accepted staples of the diet; per capita daily consumption ranges from 30 to 70 grams, five times as high as that in wealthier countries. Since the pulses are 18–25 percent protein, they are particularly important to low-income diets. The protein is double that of wheat, triple that of milled rice, and some 25 times that of cassava. In addition, the quality of the pulse protein is better than that of cereals. Pulses are one of the best sources of iron; an average serving of beans, for example, provides 6 to 12 times the iron of a slice of unenriched bread. Their riboflavin content is five times greater than most cereals, their thiamine content ten times greater. For these reasons, pulses are frequently called "the poor man's meat."

In some areas of the cereal revolution, pulse consumption has declined markedly. While the per capita wheat yield in India was increasing 25 percent between 1961 and 1972 (from 31.9 to 40 kilos per person), the per capita yield in pulses dropped 38 percent (from 29 to 18 kilos per person). The relationship is not clear, since even before the introduction of high-yielding cereal seed varieties, the

pulse decline had begun. The cereals push in the late 1960s probably accentuated the per capita pulse production decline, and in some areas, there was direct crop substitution.

The Khanna study, which took place in the heart of India's Green Revolution area, reported that while acreage for wheat and corn doubled from 1960 to 1969, cultivation of lentils "virtually disappeared."⁵ While land for growing wheat increased by 1.03 million hectares in Punjab and Haryana, land for pulses declined by 1.2 million hectares. The remarkable 44 percent decline in area devoted to pulse production was not made up elsewhere in India; throughout the country, land used to produce pulses declined 11 percent in the 1960s. In 1965, pulses constituted 16 percent of all food grain production in India, five years later 11 percent. Much the same thing occurred in West Pakistan in the 1960s.

It is unclear what pulse production would have been in the absence of the cereals revolution. The decline, as noted, apparently began prior to the introduction of the new seed varieties. In any case, pulses were neglected as research and resources concentrated on high-yielding grain varieties. Clearly, the need exists for pulse varieties with higher yields, shorter growing periods, and more resistance to insects and diseases that now take a major toll. In addition to improving efficiency, attention should be given to improving marketing techniques. In some cases, a government price support and purchase program may be desirable to make pulses more attractive to both producers and consumers.

Traditional sources of protein

Meat, milk, eggs, and fish—traditionally regarded as the source of proteins—play a small and sometimes insignificant role in the diets of low-income portions of the population. For

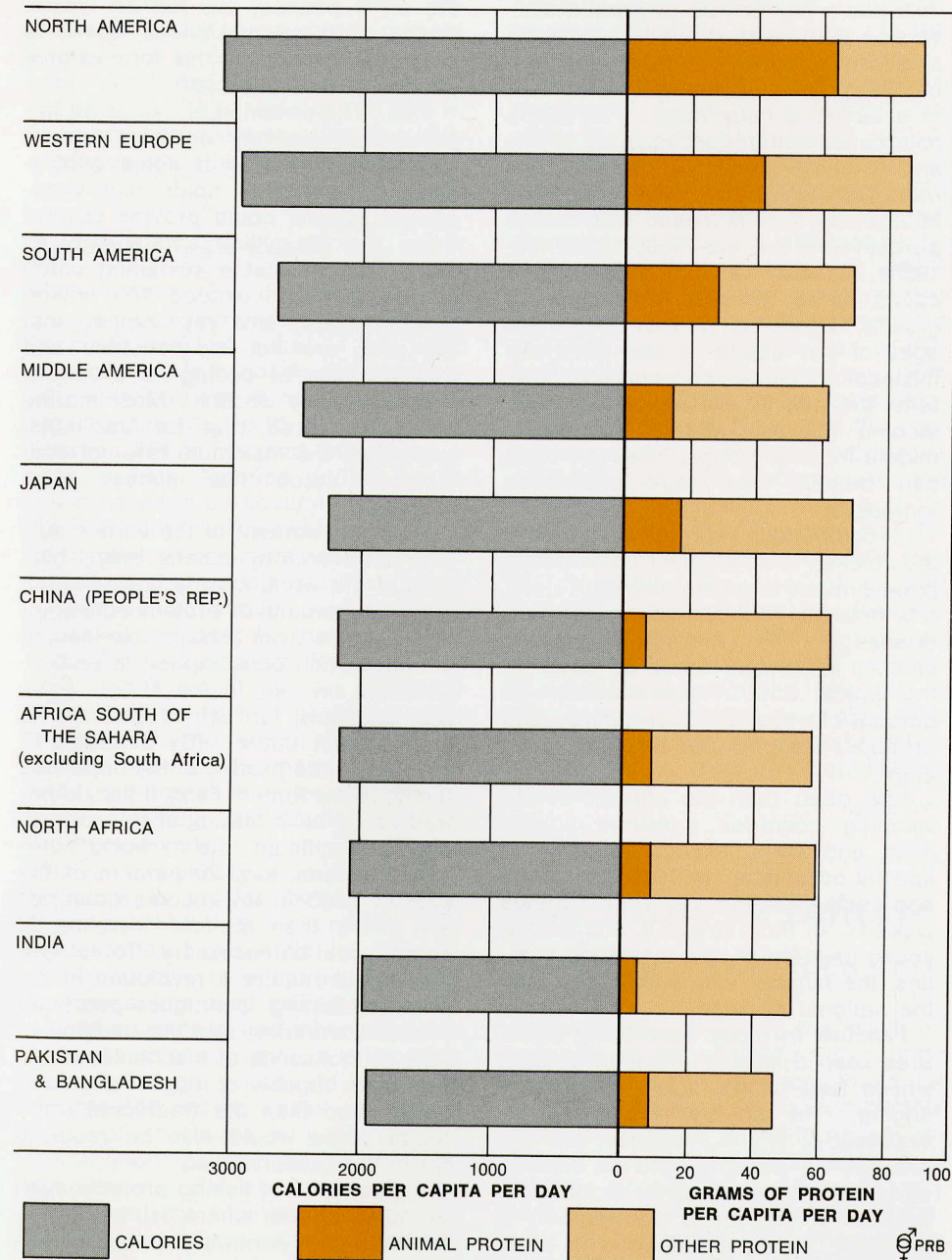
most of the world's malnourished the price of such proteins is out of reach, so that meat consumption, for example, is only a few pounds a year (compared to per capita meat consumption in the United States of 186 pounds). It is unlikely that the poor in most low-income countries will soon be able to afford nutritionally significant quantities of these foods.

It takes 5 pounds of grain to produce 1 pound of meat, an allocation few developing countries can afford, even given the dramatic increases in cereal production. Many countries are barely able to meet direct human consumption needs. A relatively low amount of grain is fed to animals in the developing countries. India uses only 0.5 percent of its total cereal supply for animal feed; the United States uses 80 percent.

Although more meat can be produced, it is another question whether it will be available for domestic consumption or whether the nutritionally needy can afford it. More meat is being raised in Central America than ever before; it seems, however, to be ending up not in Latin American stomachs, but in franchised restaurant hamburgers in the United States. A 75 percent increase in meat production in Nicaragua was accompanied by only a 3 percent increase in average consumption; a 40 percent increase in Guatemala by a 6 percent decrease in average consumption; and a 92 percent increase in Costa Rica by a 26 percent decline in per capita consumption.

Livestock production may, of course, be encouraged for export reasons. It is often appropriate in regions where land is unsuitable for other agricultural uses. Some areas that cannot produce grain do grow grass. Nevertheless, investment in livestock production may sometimes have the effect of benefiting the better off at the nutritional expense of the poor.

Fig. 2. Calorie and Protein Supply, Selected Areas



Source: Food and Agriculture Organization, *Provisional Indicative World Plan for Agricultural Development*, vol. 2 (Rome, 1970), p. 491.

Milk, Poultry, and Pork. Although milk has a higher rate of protein conversion than meat, it is still an expensive form of protein; in many developing countries a liter of milk costs half of a laborer's daily wage. Per capita milk consumption consequently is low and in some places is declining. In India, despite major dairy programs, milk production increased less than 1 percent from the mid-1950s to the mid-1960s, actually a decrease in per capita terms because of population growth. Even the already low averages of per capita consumption are misleading since consumption patterns are heavily skewed against low-income groups. Middle and lower middle income groups, however, often can benefit from milk production increases.

In comparison with other animals, the chicken is an efficient converter of plant protein to animal protein. Here, too, however, differences in yield are dramatic. The average American chicken is several times as large as the typical South Asian chicken—80 percent of which are scavengers—and produces three to four times as many eggs.

Few other than the affluent in developing countries consume poultry meat and eggs, except possibly on special occasions. In 1969, per capita egg consumption in the United States was 314; in India it was 8, and for the young children of disadvantaged families, the number was surely less than the national average.

Families in many developing countries keep a small number of poultry, whose feed comes solely from scavenging. The poultry involve no investment of any significance, and the practice no doubt should be encouraged, to achieve whatever modest nutritional or economic contribution is possible. Pork production is in many ways like poultry production. Backyard pigs, common in many develop-

ing countries, frequently are scavengers or, if penned, are fed on waste. Under such circumstances, there is little cost involved in this form of production of animal protein.

Fish. The potential of fish as an important but relatively neglected nutrient source is a matter of some controversy. One school holds that unexploited oceans could provide several times the 62 million tons caught in 1971, another that a sustained catch could not much exceed 100 million tons annually, and yet another that the seas are not inexhaustible and that because of ecological problems the catch may decline. Most marine biologists agree that for traditional table fish, the maximum level of sustainable catch has almost been reached.

While 71 percent of the earth's surface is covered by oceans, only 1 percent of the world calorie consumption—and 3 percent of protein consumption—comes from fish. In low-income countries, fish consumption is proportionately smaller; in the Middle East, fish accounts for only 1 percent of total protein intake. (By contrast, 17 percent of the protein in the Japanese diet is in the form of fish.) If fish, either traditional or nontraditional, were to play a significant role in world nutrition—meeting, say, 20 percent of the protein need in low-income countries—a more than six-fold increase in catch would be necessary. To achieve this would require a revolution in the primitive fishing techniques practiced in most countries, and the building of tens of thousands of mechanized fishing boats capable of longer range and larger load than the traditional craft. Major steps would also be required for better preservation.

Other types of fishing projects such as pond culture, where fish are multiplied under controlled conditions—particularly in paddy rice areas—deserve further exploration as a possible

means of making fish available at varied locales and at lower cost. Remarkable yields have been demonstrated—up to 5 tons an acre under ideal conditions. Also, there is the potential for large-scale use of fish in new processed forms, like the fish sausages and hams now popular in Japan.

Reducing food waste

There is little question that large portions of food produced in low-income countries are lost either in the field, in storage, or in handling and processing. The Food and Agriculture Organization estimates world food losses at between \$24 billion and \$48 billion a year. In Latin America, annual losses are believed to be about 40 percent of the total crop, in tropical Africa over 30 percent. It has been estimated that if half of the world's storage losses were prevented, enough calories would be saved to satisfy the diets of half a billion people. And disinfecting cereal grain alone would net an estimated extra 9 million tons of protein a year, equivalent to the protein needs of 375 million people. In many countries, combined losses due to rodents, insects, and fungi are double or triple the food deficits.

Given this picture, a country looking for ways to provide better nutrition might conclude that a promising area for investment was better storage facilities, modern rodenticides, chemical fumigants, improved milling and processing equipment, and other means to prevent loss of nutrients. It is tempting to assign high priority to programs designed to reduce waste—a problem made all the more poignant by the malnutrition caused by large food deficiencies. But reduction of food waste requires changes of practices and substantial investments that are not easily achieved. Also, waste in agricultural production, processing,

and distribution is economically the same as waste in inefficient industrial, power, or other branches of the economy.

In any area, such waste can be considered a cost of production, one of the inputs needed for the final product, arising from the inefficiencies of economic activity along the way. Will the largest increases in supply be obtained by reducing destruction by pests in the field; by reducing losses in storage and transport; by increasing production through greater investment in seeds, fertilizers, pesticides, or irrigation; by increasing recovery from the milling process; or by some combination of these? How does the economic return from the most productive of these measures compare with the return on investments elsewhere in the economy? Any country that focuses its solutions on waste alone may be committing the error of nutrient autarchy—sole reliance on domestic production of nutrients. As long as external trade is possible, the question of agricultural waste becomes part of the supply problem generally—how best to exploit an area's comparative advantages to meet the population's needs.

The Crisis in Infant Feeding Practices

An unusual depletion in the crude oil reserves of an oil-producing country of Asia or Latin America would be termed a crisis. Yet a comparable crisis, involving a valuable natural resource and losses in the hundreds of millions of dollars, is going virtually unnoticed in many of the poor countries of the world. The resource is human breast milk, and the loss is caused by the dramatic and steady

decline of maternal nursing in recent decades.

Breast feeding is the traditional and ideal form of infant nutrition, usually capable of meeting a child's nutritional needs for his first four to six months of life. Even after the essential introduction of supplemental foods, human milk can serve as an important continuing source of a child's nutritional well-being. From the sixth to the twelfth month it can supply up to three-quarters of a child's protein needs and a significant portion for some months beyond.

For most infants in low-income countries, prolonged breast feeding is vitally necessary to growth and, quite often, survival, as it represents the only easily available source of protein of good quality containing all the essential amino acids. Yet, in many developing countries, mothers are abandoning breast feeding. Twenty years ago, 95 percent of Chilean mothers breast-fed their children beyond the first year; by 1969, only 6 percent did so, and only 20 percent of the babies were being nursed for as long as two months. Potential breast milk production in Chile in 1950 was 57,700 tons, of which all but 2,900 tons, or 5 percent, were realized. By 1970, 78,600 tons (or 84 percent) of 93,200 tons were unrealized. The milk of 32,000 Chilean cows would be required to compensate for that loss. In Kenya, where the decline in breast feeding is less dramatic, the estimated \$11.5 million annual loss in breast milk is equivalent to two-thirds of the national health budget or one-fifth of the average annual economic aid. In the few developing countries where surveys of breast feeding have been conducted over the years, the common pattern is one of significant decline.

In most low-income countries, breast feeding is the general rule in rural areas. Its abandonment is primarily an urban phenomenon, often not so

much because urban mothers work as because bottle feeding is one of the sophistications of city life the urban migrant adopts.

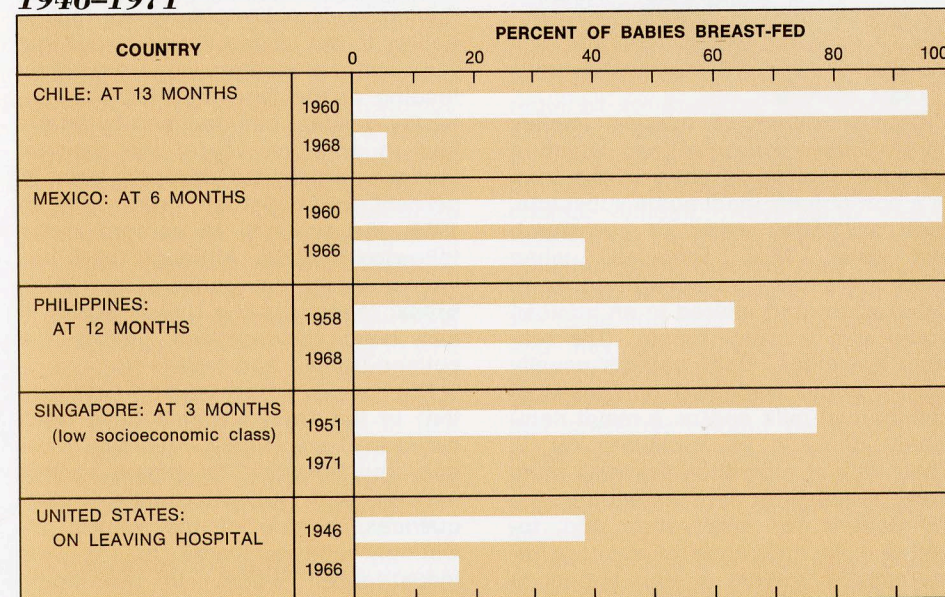
Three-quarters of all mothers in the rural Punjab in India still breast-feed 20 months after delivery, half at 26 months, and a quarter at 33 months. In major Indian cities, however, approximately one-third of the mothers either do not begin nursing or discontinue it within a year. The concentration of the loss of breast feeding in urban environments is especially alarming because cities in developing countries are undergoing mammoth growth. In addition, as communications techniques become more effective, city habits and life styles will have an increasing influence on rural societies.

An estimated 87 percent of the world's babies are born in the developing countries, about a quarter of them in urban areas. If 20 percent of the estimated 27 million mothers in urban areas do not breast-feed, the loss in breast milk is \$365 million. If half of the other 80 percent do not continue to breast-feed after the first six months, the total loss reaches \$780 million. These estimates, however, clearly understate the situation; losses to developing countries more likely are in the billions.

Breast feeding as birth control

In terms of national development, lactation has another major economic asset—its link to family planning. As a key to child survival, better nutrition through breast feeding may be an important precondition for reducing birth rates. Another benefit of breast feeding is its role in limiting conception; in some societies, in fact, it may constitute a major form of contraception. There is little doubt that breast feeding offers better protection against pregnancy for up to 10-12 months

Fig. 3. Extent of Breast Feeding in Selected Countries and Years, 1946-1971



Sources: D. M. Sanjur and others, "Infant Feeding and Weaning Practices in a Rural Pre-Industrial Setting," *Acta Paediatrica Scandinavica*, Supplement 200 (1970), p. 15; M. L. Gabucan-Dulay, "Current Feeding Patterns as Observed among 1,000 Filipino Infants," *Philippine Journal of Pediatrics*, vol. 19 (April 1970), p. 101; F. B. Mönkeberg, "The Effect of Malnutrition and Environment on Mental Development," *Proceedings of Western Hemisphere Nutrition Congress II, San Juan, Puerto Rico, August 1968* (Chicago: American Medical Association, 1969), pp. 216-20; Wong Hock Boon, *Breastfeeding in Singapore* (Singapore: J. L. Morison Son and Jones [F. E.] Pte. 1971); and Herman F. Meyer, "Breast Feeding in the United States," *Clinical Pediatrics*, vol. 7 (December 1968), p. 709.

than does the sort of haphazard and ineffective contraception practiced in many places.

The pregnancy-preventing effect of lactation is firmly rooted in the folklore of unsophisticated societies. Recent studies have lent credence to the notion. One investigation reported that the incidence of pregnancy in the first nine months after childbirth of nonnursing mothers was twice that of mothers who breast-fed, including those who simultaneously used other foods. Others confirm that although breast feeding does not serve as a perfect contraceptive, the risk of pregnancy is relatively small for mothers whose babies receive only breast milk.

The contraceptive value of lactation is most effective if in the first four to

six months the infant receives only human milk, for the sucking stimulus appears to inhibit ovulation. In the lactating mother, menstruation and ovulation are delayed from 10 weeks to as long as 26 months. In Taiwan it was estimated that lactation prevented as many as 20 percent of the births that would have occurred otherwise. In India the same ratio would mean prevention of approximately 5 million births a year.

Costs in infant health

Just as breast milk can be the major source of nutrition, the failure to provide breast milk is a major cause of infant malnutrition and mortality. And just as premature weaning is harmful,

human milk unsupplemented with other foods is, after four to six months, inadequate both in protein and calories. A child fed breast milk only until the age of 12 or 18 months becomes "breast starved."

Discontinuance of nursing implies an alternative source of food, which in the early months is often in the form of a nutritionally inadequate substitute, such as barley water or cornstarch and water. Milk "formulas," when used, are usually mixed with contaminated water and offered in an unclean bottle with a crusty nipple. The reasons are clear. Poor parents usually cannot afford sustained purchases of commercial milk and as a result commonly dilute it or substitute for it. Their lack of education prevents them from reading or understanding the instructions for preparation and, together with ignorance of sanitary requirements, fosters a high incidence of illness. Even mothers aware of hygienic needs often find it difficult to meet them with limited and unclean water, inadequate fuel, poor storage, and a single bottle and nipple. For these reasons, bottle-fed infants have illnesses, especially diarrhea, more frequently, more severely, and earlier than breast-fed babies.

Breast milk is healthful; it meets most of the metabolic needs of the baby; it contributes to good growth; it is clean, thus lowering the risk of intestinal illness and general infection. Furthermore, it provides a host of protective factors. Breast-fed babies are more resistant to malaria and to infection caused by bacteria or viruses (including the polio virus). And they are less likely to suffer from rickets and iron-deficiency anemia.

Modernization and the decline in breast feeding

The current trend away from extended nursing in most of the poorer countries

apparently has been strongly influenced by the wealthier ones. A continuing study nationwide of 2.5 million babies in the United States found that the number of mothers who were breast feeding at the time they left the maternity hospital had declined by nearly half in only ten years; the national average, which had dropped from 38 percent to 21 percent from 1946 to 1956, slid again to 18 percent in the following decade. Although there has been a recent resurgence of interest in breast feeding in the United States, it has been concentrated among the college-trained and well-to-do.

Declines in breast feeding similar to that in the United States have been noted in Great Britain, Australia, Sweden, and Poland. The stigma against nursing, with its unfortunate consequences, is one of the values unwittingly communicated to the less industrialized world. In developing countries, artificial feeding—fashionable at first only among mothers of higher income with an awareness of hygienic needs—has penetrated to middle- and even lower-income families, especially in urban settings with their fully developed advertising and other communications and their premium on sophistication.

What are the causes for the dramatic decline in breast feeding? Encroaching urbanization and modernization and new social values are significant influences. Breast feeding is often looked on as an old-fashioned or backward custom, and, by some, as a vulgar peasant practice. Indeed, anthropologists, struck by the relationship of artificial feeding to societal change, have used the duration of nursing as an inverse measure of acculturation for some countries. In most developing countries, the greater the sophistication, the worse the lactation; the bottle has become a status symbol.

Failure of lactation is one of the responses to the stress of moderniza-

tion. Among the tensions in a changing environment is the mother's anxiety about her capacity to breast feed. Her failure to initiate or to continue breast feeding is rarely traced to a physical cause but often to psycho-physiological causes. Changing social attitudes regarding the body reinforce the trend. Convenience is also a factor in the abandonment of breast feeding. Women no longer bound by tradition and now enabled by the changing pattern of home life to take advantage of an increasing number of diversions have turned to artificial feeding to free themselves from the constraints of motherhood. Although this is especially true of those who wish to join the organized work force, they are only a small part of the women who have abandoned breast feeding.

A conservation policy

Given societal sensitivities and the highly personal nature of the subject, is it possible to intervene to reverse this trend? The most essential objective of a campaign to counter the current trend is improved understanding of the benefits of breast feeding and the dangers of forgoing it. (Linked with this should be an effort to encourage added caloric intake for the mother during the nursing period and adequate food supplements to the child in the second six months of life.)

The stark facts about illness and death among nonbreast-fed babies in low-income countries must be convincingly communicated. Where feasible, the message that human milk is a safe, ready-made, simple, and inexpensive form of nutrition should be carried via mass media because of their effectiveness in changing food habits. The same advertising techniques that are partly responsible for the increase in artificial feeding can be used to counter the trend.

One forceful step toward halting the

undesirable trend away from breast feeding is government action to control the advertising that might best be described as "antinutrition education." At a minimum, advertisers should be required to abandon the misleading claims of some patented baby foods, both explicit and implicit. Intrusion on an existing commercial activity is, of course, difficult. Advertising means revenue for the media and sales to the manufacturers, benefits they will not relinquish without battle. Food firms are large and their markets extensive, and they are not without their influence on government. If political realities make regulation impossible, informal pressures should be applied to make the food companies aware of the harm their products can do and to encourage voluntary compliance to some standards.

Governments can encourage breast feeding by making it more convenient. In urban areas where privacy is virtually nonexistent, inexpensive facilities can be provided. Just as governments build bus stands and public restrooms, so they might provide small structures in crowded downtown areas for nursing mothers. Similarly, special rooms for nursing could be set aside in factories and other places of employment. Mothers who breast-feed might also be given incentives. For the working mother, this may mean government regulations requiring that she be allowed nursing time. Monetary and material bonuses may also serve as inducements for mothers who nurse their youngsters.

Steps can be taken to stem the loss of such a major resource. The size and implications of the problem should be examined and techniques designed to deal with it. For the vulnerable infant and young child, an effective public effort to counter the current trend may be of greater significance than any other form of nutrition intervention.

The New Foods

The prospect of meeting the nutrition needs of the young with appropriate food at the appropriate age is enhanced by new technologies that have dramatically reduced the cost and effort of providing good nutrition. Although no panacea, these technologies are of major significance. Despite all the talk about the scale of the malnutrition problem, attempts to combat it have been modest, chiefly because of the absence of a powerful, low-cost method for short-cutting the slow and passive reliance on income growth.

Hope today lies in foods that a decade ago would have been dismissed as fanciful. Perhaps more important, new food concepts have evolved that may lead to substantial advances. Man can now sprinkle synthetic micronutrients while milling flour; the child fed a few slices of bread baked from that flour has the vitamin, mineral, and protein equivalent of a diet studded with fruits, vegetables, and milk. Or man can produce a whole range of palatable new foods, bolstered by nutritious oilseed products that until a few years ago were considered unsuitable for human consumption.

The new nutrition technologies can be divided into two broad categories: those concerned with the enhancement of the nutritive value of existing foods by fortification and those concerned with the formulation of new foods. Key to the success of both approaches are new low-cost ingredients, a large number of which have been developed in recent years.

Fortification

Where foods can be centrally processed, one of the most attractive means for better nutrition is fortification—bolstering the nutritive value of processed foods already prominent in the diet. The use of existing foods as

carriers for additional nutrition is not new, but mass exploitation of the idea to benefit nutritionally needy countries is. In the mid-1930s, a substantial segment of the U.S. population was deficient in iron, thiamine, niacin, and riboflavin, and diseases clearly caused by nutritional deficiency—*anemia*, *beriberi*, *pellagra*, and *ariboflavinosis*—were prevalent. Research led scientists to the concept of adding the necessary ingredients to flour, in order to get them into one of the most commonly used food items: bread.

During World War II, bread enrichment was made mandatory in the United States; when the order was rescinded at the end of the war, millers and bakers continued the process so that 92 percent of all commercial white bread and nearly all retailed flour in the United States is enriched today. As a result, at least partly, many of the diseases that were on the rise in the United States in the late 1930s have virtually disappeared. Similar results have been obtained with the enrichment of flour and margarine in Newfoundland, and in an experimental rice enrichment program in the Philippines. Iodization of salt has also brought striking reductions in the incidence of goiter in several countries.

Fortification is not without its limitations. Only those people who rely on marketed, processed foods benefit. The fortification of milled cereals, for example, will not help people in a rural subsistence economy who grow and grind their own. Moreover, a viable fortification project depends on large-scale central processing. In rural areas, where inhabitants buy locally grown and processed grain, special equipment and controls would be required in thousands of small rice and wheat milling units.

Despite the limitations, however, fortification is an attractive mechanism to provide better nutrition. It does not require changes in eating, cooking, or

purchasing habits. Ideally, added nutrients do not affect the traditional character of the food; it looks, feels, tastes, and smells exactly like the unfortified product. Generally, fortification is not a costly way—often it is the least costly—to provide nutrients to the needy, and even the “nutrient wastage” incurred in the broadside delivery to the non-needy does not alter this fact. Few, if any special marketing measures are required for fortified products—no special packaging, promotion, or merchandising, no separate distribution apparatus.

The costs of vitamin and mineral supplements in processed foods is extraordinarily small. Fortification with vitamins A and D adds 0.04 cent to the cost of a quart of milk, and fortification of processed cereal grain with standard vitamins averages 0.02 to 0.03 cent per pound. The iron compound necessary to fortify salt costs 4 to 6 cents per capita per year, the iodate one-sixth of a cent. If only one in five consumers of the fortified food is in need, the total cost per beneficiary is still quite low. Protein supplementation is more costly than vitamin and mineral additions but is still considerably less expensive than conventional protein sources.

When costs are minute, they become buried in the processing cost. The modest charges for vitamins and minerals added to flour, for instance, are usually borne by the baking industry. When protein is added, however, cost becomes a factor and the question is who pays. If the consumer is to bear the cost, should the government make fortification mandatory? If so, will the consumer, because of the higher price, buy a smaller quantity of the fortified food or less of another basic food, What are the nutritional tradeoffs? The obvious alternative to the consumer's paying the increased price is outright subsidization by the government or by external aid agencies.

Carriers for fortifiers can be selected either by identifying centrally processed foods eaten by the target population and determining what nutrients these foods can carry or by beginning with the necessary nutrients and finding suitable carriers. The most common carriers currently are wheat flour, bread, milk, water, salt, margarine, cooking oil, rice, pasta, breakfast cereals, confections, and processed corn products.

Thus far, fortification efforts have been concentrated in the industrialized countries. The exceptions include rice in Thailand and the Dominican Republic; small quantities of tea in Pakistan; margarine in Brazil, Costa Rica, Chile, and Turkey; and wheat products and cooking oil in India. The opportunities to help reduce or even eradicate nutritional deficiencies in low-income countries are vast. There is room for much more imaginative use of the fortification vehicle and more persistence in seeing efforts through to implementation. If, for example, a country's entire sugar or salt supply were fortified with iron or vitamin A, the national incidence of nutritional anemia or blindness might be substantially reduced.

Formulated foods

Recent research has concentrated on the development of a blended food—a mixture of processed cereal and nutritious and widely available oilseed. The principle, long used successfully for animal rations, is simple: combine traditional cereal grains that are deficient in one or more of the amino acids that make up protein with foods that are rich in them. The principle has been followed instinctively for centuries in many countries. In South Asia, pulses (*dal*) commonly are eaten with wheat-based *chapatti*; in the Middle East, ground chickpea (*hummos*) or sesame paste (*tahini*) with round

Table 5. Cost and Source of Selected Vitamins and Minerals

Nutrient	Source	Cost per year to supply 5-year-old's total need, dollars ^a
Vitamin A	Cod liver oil	3.08
	Raw carrots	0.48
	Butter	28.14
	Synthetic fortifier	0.02
Vitamin D	Mass dose	0.02
	Cod liver oil	4.94
	Fish	32.17 ^b
Thiamine (B ₁)	Synthetic fortifier	0.01
	Shelled peanuts	24.17
	Dried beans	8.67
	Whole wheat flour	26.73
Riboflavin (B ₂)	Synthetic fortifier	0.01
	Nonfat dry milk	30.54
	Eggs	18.40
	Whole wheat flour	99.28
	Synthetic fortifier	0.01
Niacin	Chicken	34.55
	Whole wheat flour	43.44
	Dried beans	33.02
	Synthetic fortifier	0.02
Calcium	Fresh milk	30.78
	Dried beans	22.28
	Spinach	29.74
	Micronutrient fortifier ^c	0.08
Iron	Liver	16.85
	Dried beans	10.53
	Spinach	11.21
	Micronutrient fortifier ^d	0.13

Sources: Benjamin T. Burton, ed., *Heinz Handbook of Nutrition* (2d ed., McGraw-Hill, 1965); John W. Gage, *The Cost of Fortifying Foods with Vitamins* (Hoffman LaRoche, 1970); "25 Million Children May Go Blind," *Express News Service* (India), July 6, 1968; World Health Organization, *Requirements of Ascorbic Acid, Vitamin D, Vitamin B₁₂, Folate and Iron*, Technical Report No. 452 (WHO, 1970).

^a Ingredient cost only; does not include cost of carrier.

^b Varies with type of fish.

^c Calcium phosphate.

^d Ferrous sulfate.

wheat breads (*pita*); in Latin America, *frijoles* with *tortillas*; among poor blacks in the United States, hominy grits with black-eyed peas; all of the combinations increase both the quantity and quality of protein. (A favorite cereal-oilseed mix in the United States is the peanut butter sandwich.)

Blended cereals are the most popular but only one of a range of new

foods. These important innovations designed to satisfy dietary needs might be divided into:

1. *Facsimile foods*. Imitation food is intended to be as nearly like the taste and appearance of a food already part of the diet as possible. Margarine, made with such nonmilk fats as cottonseed, soybean, and safflower oils,

is the best known and most successful example of the transformation of low-cost vegetable materials into an imitation product.

2. *Variations of existing products*. Food "variations" make no pretense of imitating current products, but do take advantage of consumer preferences. For example, a number of companies have produced protein beverages that are bottled and marketed to take advantage of the demand for soft drinks. A caramel-flavored beverage is sold in Brazil, a fruit-flavored one in Surinam, a banana-flavored one in Guyana, and a chocolate-flavored one in Iran.

3. *New eating concepts*. The "new eating concept" is in many ways the most difficult change to make, since it requires a complete alteration in purchasing and eating patterns. An example of this in the United States is Instant Breakfast, which is designed to offer a quick and convenient way to consume a nutritionally balanced meal, or its forerunner, Metrecal, which incorporates essential nutritional needs in a dietetic beverage.

The new ingredients

Whether speaking of fortified or formulated foods, the success of the "new foods" depends on the "new ingredients"—that panoply of food components unknown a decade ago or, if known, seldom thought of as capable of being consumed by humans. Attention here is concentrated on protein ingredients, although it should be recognized that protein deficiency is only one of several nutrition problems facing low-income countries, and in some countries may not be the major one.

The family of foods that has received the most attention as fortifiers

or ingredients of the formulated foods are the oilseeds; in a 1971 survey, for instance, 93 percent of the new foods reviewed used an oilseed as the protein base. In general the oilseeds are both low in cost and high in nutritive value. Their most striking characteristic, however, is abundance. Approximately 110 million tons are harvested annually, mostly in countries of nutritional need. The 1970 oilseed production contained on the order of 55 million tons of protein—enough to meet, several times over, the total protein requirements of the world. With token exceptions, however, oilseed protein is not consumed by those in need. In fact, many of the protein-deficient countries are large exporters of oilseed meals. India is the world's largest exporter of groundnut and sesame, and ranks only after the United States as an exporter of all oilseed meals.

As its name implies, oilseed is grown mostly for its oil, which is used primarily for cooking. The oil is separated from the seed either by traditional screw pressing, or, more recently, by solvent extraction. The residue "oilseed cake" can be refined and used as the protein ingredient for human-grade foods. The meal of major oilseeds, which is about 50 percent protein, is used most often, however, as animal feed or fertilizer. Ironically, in some countries this by-product of vegetable oil poses a disposal problem.

Because the meal is a by-product, it is an economically attractive protein source. The price of the typical oilseed is 7 cents a pound, of the residue cake 4 cents. From this an oilseed flour can be produced for 12 cents a pound; by comparison, nonfat dry milk costs at least twice as much, and other forms of animal protein upwards of eight times as much. The quality of oilseed protein is not as high as that of animal protein but is considerably higher than that of cereals alone.

Although certain of the oilseeds are deficient in one or more of the essential amino acids, they are generally high in those that cereals lack; hence the virtue of mixing the two.

Included among the oilseeds are soybeans, cottonseeds, groundnuts (peanuts), sesame, coconuts, sunflower, and rapeseeds. Of lesser importance at the present are mustard seed and safflower seed. All rank among the world's least expensive and most available sources of protein. The principal difficulties in exploiting them for human consumption are color, toxic factors, digestibility, and palatability.

Grain protein concentrates

In the milling of grains, much of the protein value is lost. After processing, 100 pounds of wheat generally are reduced to 60 to 75 pounds of flour. The remainder, known as mill feed, is a nutritionally rich portion of the wheat that is customarily used for animal feed. Mill feeds have been bypassed as human food because of their high fiber content, which affects their digestibility and baking characteristics. In the mid-1960s, a simple method of milling portions of the mill feeds was devised to produce a wheat protein concentrate (WPC) with little fiber and a high quality protein. WPC is added to flour, raising the protein content of the flour and lowering its unit cost.

Rice, like wheat, loses many of its nutritious constituents in the processing. The bran removed during milling has a high vitamin content and is 12-13 percent protein. Making a rice concentrate with the bran, however, poses greater complications than making a concentrate of wheat. Rice bran has a high fiber content and includes oil that must be extracted before the protein can be used. Further, rice is seldom ground into flour to which a concentrate could be added. Nor do

rice-eating societies usually have an alternative ground cereal that could be fortified with rice fractions.

Single cell protein

Single cell protein (SCP) is a generic term for protein flour derived from any of a series of unicellular microorganisms—yeast, bacteria, fungi—that can be grown on a variety of abundant and inexpensive culture mediums, such as oil waste, natural gas, molasses, paper-mill waste, sewage, sweet potatoes, starch, and so on. Also part of the SCP family—but sufficiently different to be mentioned separately—are algae.

The UN Protein Advisory Group regards SCP as potentially a major new protein source. Microorganisms have been used for food production for centuries. In the making of soy sauce, sauerkraut, vinegar, yogurt, beer, yeast for oven-baked products, and certain cheeses, the organisms are part of the food process itself. Only in the past decade, however, has serious attention been directed to putting the single organisms to work to produce mass quantities of protein.

Because the organisms are continuously at work, single cell protein can be produced in very short periods. Whereas a 1,000-pound steer produces 1 pound of protein in twenty-four hours, and 1,000 pounds of soy produce 92 pounds, it is possible for 1,000 pounds of single cell organisms to produce 1,000 pounds. In other words, cattle double their mass in one to two months, chickens in two to four weeks, grass and some plants in one to two weeks, but SCP in less than two hours. The production speed of SCP also offers unique advantages in genetic experimentation—it produces a complete generation of products every three to five days.

Despite its many assets, the future of SCP for human consumption is not

clear. A low-cost SCP product will require a substantial production facility and market. A 50,000-100,000-ton plant is necessary for economic production, since the unit costs are 40 percent greater in a 10,000-ton plant than in a 100,000-ton plant. Even at that volume, SCP, although cheaper than milk, may not be competitive with oilseeds.

Algae are a special brand of single cell protein. Their production depends on a large body of water and a great deal of sun. Much of the living material in the ocean feeds on algae; the estimated quantity available is more than 100 tons yearly for each person in the world. Algae consumption is already common in some parts of the world. Natives living around Lake Chad in Africa skim a blue algae from the waters, dry it, and bake it into a cake. The product is used as a meat substitute or is mixed as a thick sauce with millet balls and is the chief source of protein in the diet. Substantial quantities of algae, some harvested, some cultivated, are consumed by the Japanese, but they are used for flavoring rather than as a protein food.

At the outset, SCP will be used to meet the increasing demand for animal-feed ingredients, perhaps to replace the 6 million tons of fishmeal and soy imported yearly by Europe. Thus the supply of animal protein for some—although usually not the neediest—portions of the society will increase; eventually SCP may increase the availability for direct human use of other protein sources now used for animal feed by replacing them.

SCP plainly has promise as a protein source, especially because of its long-range availability. The major technological breakthroughs in its utilization have been made; the requirements now are for small gains in several areas. Several hundred thousand tons will probably be produced as animal feed by the late 1970s.

Large-scale production for human use is still some years away.

Fish protein concentrate

Fish is one of the best forms of protein and potentially one of the cheapest, but except in coastal areas it is difficult and expensive to get to consumers. Because of their perishability, many fish are wasted or used as fertilizer. Fish protein concentrate (FPC) is designed to overcome the perishability problem and to make fish previously not used for human consumption an edible product at a low cost. Almost all the oil and water is removed from the fish, and the resulting protein concentrate is pressed into a dry flour that requires no refrigeration.

Fish meal has long been an ingredient in poultry and pig rations; at least a third of the fish caught are used in this way. After soy, fish meal is the most important of the internationally traded meals; the volume of 5 million tons in 1968 nearly doubled the 1960-64 average.

FPC is much more refined than fish meal. Whereas the meal is made from almost any fish caught and is processed under crude, unsanitary conditions, FPC is made from selected varieties and is processed by solvent extraction. In its most sophisticated and costly form, it is a dry, light-colored, tasteless, odorless powder containing at least 80 percent protein of excellent nutritional characteristics. It has been incorporated in breads and infant foods in South Africa, corn products in Guatemala, hard bread in Sweden, baby foods in Ethiopia and Chile, pasta in Chile, biscuits in Brazil, flavored-beverage tablets in Pakistan, and a variety of wheat products in Peru. It is, however, expensive, running about 22 cents a pound, more than twice the cost of most oilseed flours. Without signifi-

cant technological advances to lower the cost, it is unlikely that fish protein concentrate will have much impact on the nutrition problem in the near future.

Other promising areas of research and experimentation include the leaf protein concentrates, made from the leaves of such plants as alfalfa, and synthetic nutrients, including synthetic amino acids. At present, however, the oilseeds are the most attractive of the new food ingredients. Much work remains to be done before the new foods can be proclaimed to have made a breakthrough in resolving the nutrition problems of malnourished people of the world.

Improved Nutrition and the Population Dilemma

The notion of improving nutrition sometimes prompts the uncomfortable question: Why go to such efforts to keep people alive when the basic problem is too many people? Moral considerations aside, it may be that better nutrition is one of the important ingredients necessary for an effective family planning program. Although other essential factors are also involved, an important precondition for bringing down the birth rate may be to keep more children alive, and improved nutrition is one of the keys to achieving this. There is no question but that the immediate effect of reducing child mortality will be a population spurt. But against this certainty is the hope that a lowering of child mortality rates now will have an important effect in later years on reducing the population growth rate.

Throughout the developing world, family planning efforts are plagued by the same kind of program and admin-

istrative difficulties that infect any large new activity, and these are not easy or inexpensive to overcome. A major obstacle to success in such programs is the lack of an effective, easy, inexpensive, reversible, aesthetically acceptable, and easily understood contraceptive.

Even greatly improved and acceptable contraceptives, however, would solve only part of the population problem. Insufficient motivation to practice birth control is increasingly recognized as a large and more difficult obstacle.

The chief premise of much of the early family planning effort has been that ignorance, inadequacy, or non-availability of contraceptives is the cause of the burgeoning population. Reexamination of that premise now suggests that in much of the developing world most births would occur anyway, that parents consciously want many children.

The wish is a reflection of a need that the typical family history in today's poor countries makes apparent. The average family wants at least two adult sons. The reasons vary: a mark of success, of good fortune, of religious favor, of maintaining the family name and property, of ceremonial duty, of economic necessity—and always of security. In many countries the villager commonly expresses his need for sons "to take care of me when I get old."

In most poor countries, sons provide the only effective form of social security. The premium placed on male offspring is confirmed by an Indian study of vasectomized fathers, who had an average of more than three times as many sons as daughters. Another study concluded that "only as reduced mortality and morbidity provide some physical security can concepts such as planning, saving, or investing for the future have meaning, whether they are applied to one's family or to the whole society."⁶

A recent study revealed that with current estimated infant and adult death rates in India, a couple must bear 6.3 children to be 95 percent certain one son will be surviving at the father's sixty-fifth birthday. The average number of births in India per couple is 6.5.

The combined desire for adult sons and recognition of high child mortality are among the contributors to the population dilemma. This suggests paradoxically that keeping more children alive, although it inevitably will increase the population in the short run, may be a powerful contribution toward lowering the population growth rate in the long run. Experience in the Western world is not inconsistent with the notion that reduction of the death rate may be a prerequisite to reduction of the birth rate. The same seems to be true among countries such as Taiwan and Korea that are now increasing in affluence. Demographic trends in Mauritius, Ceylon, and British Guiana also suggest that as death rates decline, birth rates begin to fall.

Family size, of course, is determined by a number of very complex behavioral phenomena. What are the key factors—income, education, urbanization, and other elements of "modernization"—that govern the lag between declining mortality and fertility rates and that eventually convince people to have fewer children? What is the relative importance of lower infant mortality, the rate at which it declines, its relation to other determinants of population size at any particular rate? How powerfully, and under what conditions, could a deliberate program to drive infant mortality down to low levels contribute to an overall population policy? Many questions are still to be answered, but it does appear a reasonable hypothesis that at least a substantial further reduction of child mortality, although not a sufficient condition of itself, may be a necessary

precondition to induce a large fraction of the present population to lower the number of desired births.

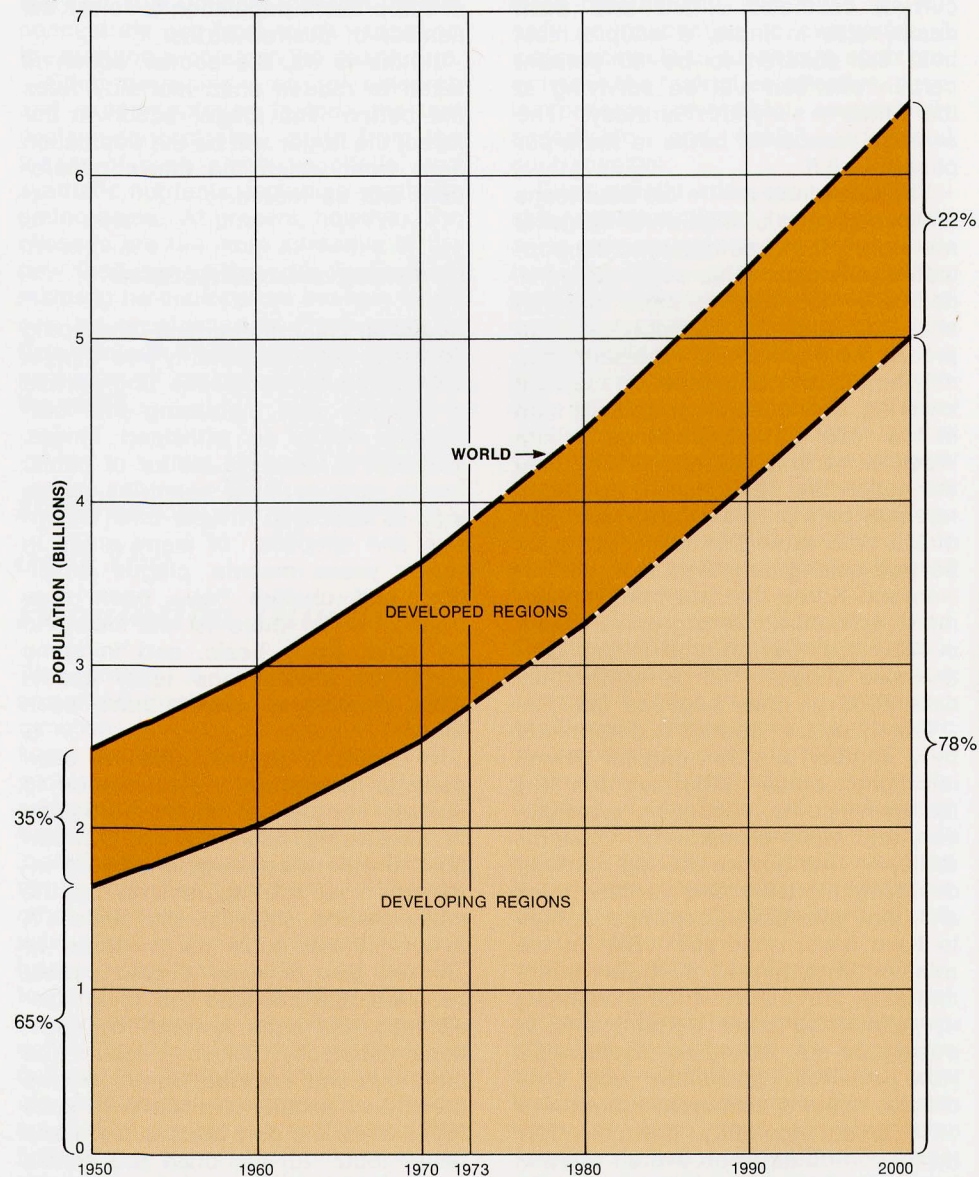
If this is so, the sooner action is taken to reduce child mortality rates the better. The longer action is delayed, the larger will be the population base from which the future generations will be reared.

Reducing mortality rates

Reducing child mortality in developing countries means primarily two things: decreasing the incidence and spread of disease and increasing the individual's ability to withstand illness. The first is largely a matter of public health, and in most countries measures to deal with it have been extensive and effective. In many areas in recent years, malaria, plague, smallpox, and cholera have been controlled. While there is still much to be done, many basic, and in some ways the easiest and least costly, steps in disease control have been taken.

In contrast, relatively little has been done to strengthen the resistance to illness. The bulk of childhood deaths in developing countries are attributable to otherwise minor childhood infections that are aggravated by the malnourished state of the child. A minor illness such as measles or chicken pox or even a cold cannot be overcome because the child's resistance has been lowered by nutritional deficiency. Diarrhea occurs and more nutrients are lost. Commonly the prescribed remedy is to withhold solid foods when the only hope is more and better food. All too often the child's malnutrition begins in the womb with the mother's own anemia and other nutrient deficiencies. Pregnancy wastage—miscarriage, stillbirth, birth abnormality—is common among malnourished women. And the live babies

Fig. 4. World Population Growth, 1950-2000



they do bear are often premature and underweight, increasing the risk of early death.

Nutrition and family size

Just as alleviation of childhood and maternal malnutrition could encourage smaller families, so the limitation of family size could in itself contribute to improved nutrition and infant survival. Simple arithmetic from Indian diet surveys demonstrates that protein availability per child in families with one or two siblings would be 22 percent higher (some 13 grams per head) than in those with four or five siblings. In most cases this additional amount would be enough to meet current protein deficits. The Indian National Institute of Nutrition has observed that youngsters with three or more older brothers or sisters constitute 34 percent of the child population but account for 61 percent of all cases of protein-calorie malnutrition in its clinic. During the Bihar famine relief program in 1966-67, the most severe cases of malnutrition were invariably children from large families. Nearly five times as much protein-calorie malnutrition was found among the younger children of large families.

The number of children also has a direct bearing on the nutritional well-being of the mother. Nutritional anemia, a major cause of illness and death during pregnancy, gets more virulent as a mother has more babies. Three times as many pregnant women with four or more children suffer from severe anemia in India as those mothers with smaller families. It is the mother who bears the sickly child with minimal chances of survival who has little interest in practicing contraception.

Possibilities for successful contraceptive programs may be enhanced if women's nutrition is improved. For

example, nutritional anemia may be a cause of the high removal rate of intrauterine devices (IUD's). If so, iron supplements could be an important ingredient of a successful IUD program. Where the loop is used, it commonly causes excessive vaginal bleeding and related iron loss, exacerbating anemia. Excessive bleeding, it has been noted, is more deleterious to poorly nourished than to adequately nourished women, and poor nutritional status may be an added stimulant to bleeding.

Future Policy Directions

Malnutrition in developing countries is a problem of huge proportions and wide-ranging implications. Combating malnutrition alone does not, of course, offer a simple solution to underdevelopment; on the contrary, nutrition is one of many interrelated determinants of human performance requiring advancement. Under some circumstances, however, better nutrition may be a precondition to the advancement of other factors and a propellant to many forms of production. In short, not only is malnutrition a consequence of underdevelopment but it is a contributing factor, a drag on the potential from which better nutrition might be provided.

The problem is even more poignant in light of the development experience of the 1960s. Even fairly successful national growth, in conventional terms, has left out substantial fractions of the populations in low-income countries—some even ending up the decade in worse shape than they started. This has prompted redefinition of development objectives and increasing real-

ization that greater attention must be paid to the quality of life. In this context malnutrition looms large.

What are required are new approaches, new research, new organizational entities, a new discipline, and most important, a new scale of concern about the problem and a concomitant new scale of action. Although a great deal of investigation clearly is needed to obtain more precise data and reduce the ranges of uncertainty, knowledge of nutrition—

the problems as well as the techniques and technologies to meet them—is at a stage where much can be done. Enough information already is in hand to justify resource allocation for nutrition on a substantial scale. The token efforts of the past are an inadequate and thus unacceptable response. It is no longer sufficient to think of nutrition in terms of projects that are doing something good or useful; they must be aimed at doing something of consequence. 

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The vital population statistics needed
~~to~~ analyze the grizzly bear pop in the yd. ac.
^{are getting over}
Pop. data gathered over a 15 year
period

367 censuses of 3.5 hrs
1969-1967 - determined from
these counts the information necessary
to develop a mathematical model
of the grizzly bear population
Such vital statistics included

age structure

Sex ratios

Reproductive rates

Mortality & survivorship rates

Longevity

These data were incorporated into a digital computer program which calculated the changes occurring in the population ~~each year~~ on a year-by-year basis, to form a deterministic mathematical model.

The model was then used to study the behavior of the population, to determine the effects of ~~various~~ changes in various biological parameters and to predict the overall pop trend after 1970 when field census data was no longer being taken.

3

Trial runs were made with the model for the 1959-67 base period. Results indicated that the population was increasing at an average rate of 2.4 % per year during this period. In all cases we found good agreement with predictions of the model and the actual behavioral characteristics of the population we had observed and recorded. We concluded that the model accurately simulated the behavior of the gizzard bear pop.

by the course of our research 264 grizzlies
were individually marked (1959-1970).
During a 12-year period 39.0%

of all bears censused were marked
ones - determined by the relation of
the number of marked grizzlies
in the population each year to the
number of those counted in the
census each year.

Then by determining the relation
between the percent of marked
bears counted in censuses each
year to the percent of those marked
animals annually killed outside
the Park we ^{figured} ~~determined~~ that an
average of 31.0% of all bears killed
outside the Park were marked ones.

The Percent kill of marked
 quizzies outside the Park
 Using these data and an average of 177
^{beams censused each year we computed the}
 The average total ecosystem
 population ~~was then computed~~
 to be 229 quizzies. The average
 number of beams censused during
 the 1959-70 period was 177,
 thus the census efficiency for
 the ecosystem population was
 77.3%

This estimate of the census
 efficiency enabled us to

6.

compute and examine past and present population levels in the entire ecosystem. Simulation runs were made using the computer model ~~and~~ with changes in grizzly bear annual mortality ^{and} ~~reproduction~~ ^{fecundity}. The most probable case shows the ecosystem population increasing from 222 animals in 1959 to 245 in 1967, then declining to 136 animals in 1974 and the population ^{still did} ~~not~~ not stabilize.

Thus we conclude that the best estimate of the present grizzly bear population in the Yellowstone

scorptum is 136 animals.
This best estimate reveals a
44.5% reduction in size of
the grizzly bear population from
a high of 245 in 1967.

This decline in grizzly bears is
a serious condition for a species
with a history of disappearances and
extinction over large areas of the
West.

Our research evidence demonstrates
that the Yellowstone grizzly has a
low reproductive rate and the
population cannot sustain high

continued
8.
mortality rates without being
threatened by extinction.

The study results suggest that
agencies responsible for the preservation
& management of the grizzly bears
must take a conservative approach
to management. They should be
extremely cautious in applying
improved management techniques
& precise in controlling & harvesting
the species.

Enforced management of Yellowstone
grizzlies, based on long term pop-
ulation statistics is mandatory if a viable
population is to survive.

Pop. Skpt.

add John's pop. warning - computer
analysis

Check pop. assembled for Biology & Inst.
of quizzly

p. 8 - 264 } quizzly bears
256 }

Incident of stalking & shooting full warning
quizzly - p. 9 (add)

p. 11 - in death should they be shot
add example

Names of assistants - p. 11

Check list - vital statistics & add other
for R. Clendenen

p. 13 Lonesome cut of #7

p. 14 describes weighing technique

p. 17 computer analysis & warning

Gizzly Bear Radiotracking & The Research & Mgt. Controversy

Long range ecological study - Intensive 1959-1967 - ^{less intensive through 1974}
Area known as the Yellowstone ecosystem - 5,000,000 acres
Population as determined through systematic counts or censuses (324 censuses 3.5 hours ea) 15 yrs.

av. pop. from 1959-67 was 229 grizzlies ranging from 222 in 1959 to 245 in 1967 dropping to 136 in 1974
av. 229

Seasonal pattern of movement - to center of park & to dumps
#48 radiotagged grizzlies

Marked 264 grizzlies - trapped & handled over 600
Den information

Ranger and movements

Most probable pop. was 245 in 1967 declining to 136 in 1974

Controversy over Guggly Bear Mgt. & numbers
Also involved freedom to do research under agreements
of understanding without harassment and destruction of
research program if results & conclusions did not jibe
with existing policy.

1969 & 1972 Meetings

NAS Bear Committee

3 sources of fact & opinion

NAS

P-S-E, IS

Tech. paper on analysis

More controversy - Bad bear manipulation

REPRODUCTIVE CYCLES AND RATES IN THE GRIZZLY BEAR,
Ursus arctos horribilis, OF THE YELLOWSTONE ECOSYSTEM

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INTRODUCTION

Grizzly bears, Ursus arctos horribilis, in the contiguous United States, have rapidly declined since the early 1800's to a number that does not now exceed 600 or 700 (Craighead and Craighead, 1973). These are found only in the high mountain country and the wilderness areas of our large national parks and forests. In Alaska and western Canada, grizzly bears are still relatively abundant.

Female grizzlies are characterized by a long life span, a relatively late sexual maturity, protracted reproductive cycles, and, as adults, high survivorship rates (Craighead et al., 1974). Their low reproductive capacity compared to other mammals is an evolutionary characteristic that relates to size and power, competence and aggressiveness of mothers, the self-sufficiency of cubs, and social facilitation among females with offspring. Because of the continuity necessary in obtaining long-term quantitative data, precise reproductive rates have not been obtained for any bear population. Yet information on reproductive rates is essential for intelligent management since neither mortality rates nor population trends can be evaluated without such information.

We describe in this paper how reproductive rates were obtained and how this biological parameter relates to the population dynamics of the Yellowstone grizzly bear.

METHODS

Bears were captured in culvert traps or shot with propulsive syringe darts containing immobilizing drugs. Following capture or immobilization,

each grizzly was ear-tagged and individually color-marked. Used in combination with color-numbered ear-tags, several hundred color combinations were possible. Many color-markers lasted 6 or 7 years without replacement and some for the entire study period (Craighead et al., 1960).

Computing Reproductive Cycle

To determine age at first pregnancy, known or established age animals were annually observed during the mating seasons (Craighead et al., 1969). We obtained quantitative data on length of the reproductive cycle by recording reproductive histories of 30 marked females over an extended period of time. Among these, all but five were aged by the cementum layer technique (Craighead et al., 1970). Litter sizes determined from annual counts of individually identifiable females were used to compute reproductive rates and the number of cubs produced per adult female per year. This reproductive rate was calculated by dividing litter size by length of the reproductive cycle.

✓ A reproductive cycle extends from pregnancy to pregnancy. Fertilization may occur during June to mid-July and parturition late in January or early February. A female normally breeds at 2 or 3 year intervals (Craighead et al., 1969).

The reproductive cycle for an individual female is obtained by dividing the reproductive period in years by the number of cycles. A female with two cycles during a 7-year period, for example, has a reproductive cycle of 3.5; a population with a total of 33 cycles and 99 reproductive years exhibits a 3.00 average reproductive cycle. The 30 females were divided into four sample groups based on number of reproductive cycles. Samples 1 and 2 include 19 females with the most complete reproductive histories.

Nine females were sub-adult when record keeping began. The third sample includes the 19 bears from Samples 1 and 2 plus five additional females. The fourth sample includes reproductive histories of all 30 females with assumed dates of last pregnancy. Number of litters, cubs per litter, amplitude of reproductive cycles, and reproductive period in years were recorded for each female. The reproductive period for each female is the sum of her reproductive cycles. A cycle is the period in years from pregnancy to pregnancy or to an assumed pregnancy. An assumed pregnancy date was projected in order to maximize information on the reproductive chronology of each female. It was usually assumed that when observation of a given female terminated, pregnancy ensued at the earliest possible date. Our assumptions tended to minimize average length of the reproductive cycle, but the average unadjusted cycle lengths (3.00, 3.00, 3.08 and 3.21) of the four samples are similar by comparison.

In a 2-year cycle, the female becomes pregnant in June or July, whelps the following February, suckles cubs through summer and winter, weans them as yearlings in the spring, then breeds and becomes pregnant following weaning.

In a 3-year cycle, the female becomes pregnant, whelps cubs, attends them as yearlings, dens with them, weans them as 2-year olds soon after leaving the den, and then breeds to begin another cycle. Weaning behavior was observed among adult females with 2-year olds. We verified conclusively that females with 18-30 month old young lactated and suckled offspring. In rare instances when a female did not enter estrus following weaning, the parental bond may have held a family unit together.

In a 4-year cycle, the female follows the 3-year cycle, but after weaning 2-year olds, she either remains anestrus or comes into estrus

without fertilization to breed the following year and become pregnant.

Discontinuous embryonic development occurs in the grizzly bear. The developmental arrest may extend from conception to time of hibernation, a period of approximately 5.5 months (Craighead et al., 1969).

Determining Age at First Pregnancy

A female was recorded as pregnant following observed copulation resulting in offspring or by extrapolation from observations of females with cubs. A female was considered sexually mature at 5.5 years, the earliest that females were known to produce litters (Craighead et al., 1969). The period in years between the earliest recorded pregnancy (age 4.5) and the actual age at which a first pregnancy occurred we termed the pre-pregnancy period. Among 30 females with reproductive histories, this period ranged from zero to 4 years. The effect of an extended pre-pregnancy period on length of reproductive cycle will be considered in calculating values for reproductive cycles.

The age at first pregnancy was recorded for 16 of 30 marked females. Eleven of these (69%) first became pregnant at 4.5, one at 5.5, three at 6.5, and one at 8.5 years of age. Although younger females copulated, none became pregnant before they were 4.5 years old (Craighead et al., 1969). The average age at first pregnancy was 5.2 years for 16 females. It was possible, but unverifiable, that some females having protracted pre-pregnancy periods conceived earlier and suffered miscarriages or fatalities of entire litters in the den. The effect on reproductive rate is nonetheless identical to failure to conceive.

RESULTS

Reproductive Cycles

Reproductive cycles of 19 marked females were calculated from known pregnancies as shown in Table 1. The number of cycles per female varied from one to three and totaled 33 for all 19 animals during a cumulative reproductive period of 99 years. Sample 1 contains no assumed pregnancies, so usable data on cycles, reproductive period and litter size are minimal. The reproductive cycle varied from 2 to 5 years. Of the 33 cycles, 9 were 2 years; 16, 3 years; 7, 4 years; and 1, a 5-year cycle. The ratio of 3-year cycles to 2-year cycles was 64 to 36 percent. For some females the reproductive period consisted of a single reproductive cycle, but included two or more cycles for others.

When the total reproductive period in years for all 19 females (99) is divided by the total number of cycles (33), 3.00 years is the average reproductive cycle. This parameter must be adjusted to include pre-pregnancy data.

Among 19 females recorded in Table 1, five were older than 4.5 years at first pregnancy. The average reproductive cycle of 3.00 was adjusted by 11 years to account for the time these females were not pregnant. With this pre-pregnancy calculation ($99 \text{ years} + 11 = 110/33 = 3.33$), the average reproductive cycle is 3.33 years.

By making assumptions as to when each of 19 females was pregnant following her last litter, it was possible to use 52 cycles totaling 156 reproductive years. Reproductive years were then calculated for each female from first pregnancy to a last assumed pregnancy. With longer reproductive

Bear No.	Age Marked	No. of Repro. Cycles in Years				Total Cycles	Repro. Period In Years	Date of Last Known Pregnancy	No. Cubs	Repro. Rates
		2	3	4	5					
5	1.5		1			1	3	1967	2	0.667
7	12.5		1	1		2	7	1965	6	0.857
10	2.5			1		1	4	1969	2	0.500
15	1.5		2			2	6	1968	3	0.500
34	14.5	1			1	2	7	1967	4	0.571
40	1.5	2				2	4	1967	4	1.000
42	5.5	1	2			3	8	1969	6	0.750
65	Adult	2				2	4	1963	6	1.500
84	Adult			1		1	4	1964	3	0.750
96	3.5		2			2	6	1968	6	1.000
101	4.5	1		1		2	6	1969	2	0.333
120	12.5			1		1	4	1964	2	0.500
125	5.5		3			3	9	1970	8	0.889
128	10.5	1	2			3	8	1969	10	1.250
144	0.5			1		1	4	1970	2	0.500
150	4.5			1		1	4	1966	3	0.750
172	11.5	1	1			2	5	1967	4	0.800
173	2.5		1			1	3	1969	2	0.667
175B	Adult		1			1	3	1962	2	0.667
Totals		9	16	7	1	33	99		77	

Table 1. Reproductive rates of 19 marked female grizzlies calculated from 33 reproductive cycles, 1959 - 1972.

histories to examine, changes occurred for individual females in average length of the reproductive cycle and in reproductive rates. The average reproductive cycle was 3.21 for these 19 females using this larger data sample.

Data used in a third computation was from 24 females having 62 reproductive cycles during a combined reproductive period of 191 years. Twenty-nine percent were 2-year cycles and 47, 16, 5, 2 and 2 percent were 3-, 4-, 5-, 6-, and 7-year cycles, respectively. From these data, we computed an average reproductive cycle of 3.26 years for 24 females.

A fourth sample comprised of 30 females (Table 2) yielded 68 reproductive cycles, a reproductive period of 231 years, and an average reproductive cycle of 3.40 years. Data used to calculate average reproductive cycles for marked females included in the four data samples is summarized in Table 3. Similarity in length of the reproductive cycles obtained from the four samples indicates that this important biological parameter is accurate.

Litter Sizes

The thirty marked females produced 68 litters. Nine were 1-cub litters; 38, 2-cub; 18, 3-cub; and 3, 4-cub litters. Fifty-six and twenty-six percent were 2- and 3-cub litters, respectively. The average litter size for the 30 females was 2.24 (Table 3).

Reproductive Rates

Reproductive rate is a function of reproductive cycles and offspring produced. To compute individual reproductive rates it was, therefore, necessary to ascertain the length of reproductive cycles of marked females and the number of cubs produced during the cycles.

Bear No.	Age* Marked	No. of Repro. Cycles in Years						Total Cycles	Repro. Period In Years	No. Cubs	Repro. Rates
		2	3	4	5	6	7				
5	1.5		1	1				2	7	5	0.714
7	12.5		2	1				3	10	8	0.800
10	2.5		1	1				2	7	4	0.571
15	1.5		3					3	9	5	0.556
34	14.5	1	1		1			3	10	6	0.600
39	5.5		1	1	1			3	12	7	0.583
40	1.5	2	1					3	7	7	1.000
42	5.5	2	2					4	10	8	0.800
65	Adult	3						3	6	9	1.500
84	Adult	1		1				2	6	5	0.833
96	3.5		3					3	9	8	0.889
101	4.5	2		1				3	8	4	0.500
112	8.5		1			1		2	9	5	0.556
120	12.5			1			1	2	11	4	0.364
125	5.5		4					4	12	10	0.833
128	10.5	2	2					4	10	13	1.300
144	0.5	1						2	6	4	0.667
150	4.5			1	1			2	9	5	0.556
163	1.5	1						1	2	2	1.000
172	11.5	1	2					3	8	7	0.875
173	2.5	1	1					2	5	3	0.600
175	10.5	1	2					3	8	4	0.500
175B	Adult		2					2	6	4	0.667
200	3.5			1				1	4	2	0.500
44	Adult						1	1	7	2	0.286
140	8.5				1			1	5	3	0.600
141	1.5		1					1	3	2	0.667
160	Adult					1		1	6	2	0.333
180	11.5		1					1	3	3	1.000
187	1.5		1					1	3	1	0.333
Totals		18	32	10	4	2	2	68	218	152	

*Bears designated as "Adult" were assumed to be at least 4.5 years of age.

Table 2. Reproductive rates of 30 marked female grizzlies calculated from 68 reproductive cycles, 1959 - 1972.

	SAMPLE GROUP			
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>
Number of Marked Females	19	19	24	30
Number of Reproductive Cycles	33	52	62	68
Reproductive Period in Years (Adjusted)	99(110)	156(167)	191(202)	229(231)
Total Number of Cubs	77	119	139	152
Average Litter Size	2.33	2.29	2.24	2.24
Average Unadjusted Reproductive Cycle	3.00	3.00	3.08	3.21
*Adjusted Average Reproductive Cycle	3.33	3.21	3.26	3.40
Reproductive Rate for Population of Marked Females	0.700	0.713	0.687	0.659

*Adjusted by including pre-pregnancy data.

Table 3. Comparison of four calculations for obtaining reproductive rates from marked female grizzlies.

In Sample 1, reproductive rates ranged from a low of 0.333 to a high of 1.500. The low represented two cubs produced in two cycles totaling 6 years, whereas the high resulted from six cubs produced in two cycles of 4 years. Of the 19 females, 4 exhibited reproductive rates of 1.000 or higher (Table 1). The average rate for all females was 0.700 (Table 3).

In Sample 2, reproductive rates were calculated for the same 19 females using 52 reproductive cycles and 156 reproductive years. By analyzing additional cycles, some of the individual reproductive rates of these females were altered (Table 4). Three rates remained unchanged, 10 increased by an average of 0.079, and 6 decreased by 0.104 for an 0.009 overall average increase in all rates. This gave a 0.713 average reproductive rate for all 19 females compared to 0.700 for Sample 1. A further comparison of Samples 1 and 2 showed that while total cub production increased from 77 to 119, the number of reproductive cycles also increased. Sample 2 revealed a lower average litter size and a shorter average reproductive cycle (Table 3).

The sample of marked females was increased to 24 and reproductive rates calculated from a total of 62 cycles and 202 reproductive years (191 plus 11 years of pre-pregnancy). This gave a reproductive rate of 0.688.

In Sample 4 of 30 females, the average reproductive cycle of 3.21 years and the total reproductive period of 218 years were adjusted to include 13 pre-pregnancy years. The adjusted cycle became 3.40 years, and the adjusted reproductive period increased to 231 years, giving a reproductive rate of 0.658 (Table 5).

Reproductive rates based on only one recorded reproductive cycle illustrated the relationship between cycle length, number of cubs, and

Bear No.	Repro. Rates from 33 Repro. Cycles	Repro. Rates from 52 Repro. Cycles	Change in Repro. Rates with Change in Sample Size	
			33 R.C.	52 R.C.
5	0.666	0.714		+0.048
7	0.857	0.800	-0.057	
10	0.500	0.571		+0.071
15	0.500	0.555		+0.555
34	0.571	0.600		+0.029
40	1.000	1.000		0.000
42	0.750	0.800		+0.050
65	1.500	1.500		0.000
84	0.750	0.833		+0.083
96	1.000	0.888	-0.112	
101	0.333	0.500		+0.167
120	0.500	0.364	-0.136	
125	0.888	0.833	-0.055	
128	1.250	1.300		+0.050
144	0.500	0.666		+0.166
150	0.750	0.555	-0.195	
172	0.800	0.875		+0.075
173	0.666	0.600	-0.066	
175B	0.666	0.666		0.000
TOTALS	14.447	14.620	-0.621	+0.794
	R.R. = 0.760	+0.173 R.R. = 0.769	+0.173	

Table 4. Comparison of reproductive rates of 19 marked female grizzlies (excluding pre-pregnancy data).

Cycle Length (yrs)						Total Cycles	Repro. Period (yrs)		No. Cubs	Repro. Rate	
<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>		<u>Unadjusted</u>	<u>Adjusted</u>		<u>Unadjusted</u>	<u>Adjusted</u>
18	32	10	4	2	2	68	218	(+13) 231	152	0.697	0.658
(No. of cycles)											

Calculations

$$\frac{\text{Total Cubs}}{\text{Total No. Litters}} = \frac{152}{68} = \underline{\underline{2.24}} = \text{Average Litter Size}$$

$$\frac{\text{Total Reproductive Period in Years}}{\text{Total Number Cycles}} = \frac{218}{68} = \underline{\underline{3.21}} = \text{Unadjusted Reproductive Cycle}$$

$$\frac{\text{Total Cubs}}{\text{Total Reproductive Period in Years}} = \frac{152}{218} = \underline{\underline{0.697}} = \text{Unadjusted Reproductive Rate}$$

$$218 + 13 = 231 \text{ (Total Reproductive Period in Years Adjusted by Pre-Pregnancy Data)}$$

$$\frac{\text{Adjusted Total Reproductive Period in Years}}{\text{Total Number Cycles}} = \frac{231}{68} = \underline{\underline{3.40}} = \text{Average Reproductive Cycle}$$

$$\frac{\text{Total Cubs}}{\text{Adjusted Total Reproductive Period in Years}} = \frac{152}{231} = \underline{\underline{0.658}} = \text{Average Reproductive Rate}$$

Table 5. Calculation of average reproductive rate for 30 adult females.

reproductive rate. As an example, one female had a very low reproductive rate (0.286) because of a long 7-year cycle, while another had a high reproductive rate (0.600) despite the production of three cubs during a 5-year cycle. The 0.667 reproductive rate of still another female exceeded the average for all females (0.658) because a 3-year cycle compensated for her low production of two cubs. The average reproductive rate was 0.482 for six females, each with only one reproductive cycle.

For a species having a low reproductive rate, even minor changes in rate affect population growth. The reproductive rates from Sample 4 are believed more accurate than those from Samples 1, 2, and 3 because they better represent the population by reflecting reproductive behavior over a longer period of time and for a larger number of females.

Maximum and Minimum Reproductive Rates of Marked Females

Maximum reproductive rates of individual bears, including variations resulting from changes in sampling, are presented in Table 6. For example, female No. 128 exhibited a reproductive rate of 1.250 during a period of 8 reproductive years and 1.300 in a 10-year period. Female No. 96 had a reproductive rate of 1.000 during 6 reproductive years, but this declined to 0.889 over a period of 9 years. Although the data indicate that one female exhibited a reproductive rate of 1.500 during a 6-year period, it is highly unlikely that she could sustain this throughout her entire reproductive life. Data suggest that a maximum for several females averaged 1.17 or, in round figures, about one cub per adult female per year.

Although the minimum reproductive rate recorded for an individual female was 0.286, this was for only one reproductive cycle and was not considered representative. Minimum rates for Samples 1, 2, and 3 (Table 7)

<u>Bear No.</u>	<u>Sample 1 (19)</u>	<u>Sample 2 (19)</u>	<u>Sample 3 (24)</u>
40	1.000	1.000	1.000
65	1.500	1.500	1.500
96	1.000	0.889	0.889
128	1.250	1.300	1.300
Average	1.188	1.172	1.172

Table 6. Maximum reproductive rates of individual grizzly bears for which more than one reproductive cycle was observed, 1959 - 1972.

<u>Bear No.</u>	<u>Sample 1 (19)</u>	<u>Sample 2 (19)</u>	<u>Sample 3 (24)</u>
101	0.333	0.500	0.500
120	0.500	0.364	0.364
10	0.500	0.571	0.571
15	0.500	0.556	0.556
Average	0.458	0.498	0.498

Table 7. Minimum reproductive rates of individual grizzly bears for which more than one reproductive cycle was observed, 1959 - 1972.

show that female No. 120 had a reproductive rate that averaged 0.364 over an 11-year period. With the exception of this female, the minimum rate for individuals increased as the number of reproductive years sampled increased. The average of four females in Samples 2 and 3 was 0.498; therefore, an average minimum reproductive rate among marked females was approximately half the maximum, or in round numbers, 0.5 cub per adult female per year.

Reproductive Rate for Ecosystem Population

As said earlier, the 30 marked females provided accurate estimates of the reproductive cycle of 3.40 and rate of 0.658. An additional 25 marked females, though omitted from reproductive cycle calculations because of observational discontinuities, were combined with the 30 to compute a long-term reproductive rate. This long-term rate was derived from 15 years of annual counts of females with litters and the reproductive cycle length of 3.40 years (Craighead *et al.*, 1974). The resulting value of 0.626 for the reproductive rate was, because of increased sample size, considered the most accurate long-term rate.

Reproductive Longevity

One female was 14.5 years old when marked, and produced her last litter of two cubs at the age of 22.5, weaning them when she was 24.5. Two females produced litters when they were 19.5 and two others when 17.5 (Table 8). The longest observed physical longevity for a female is 25 years; therefore, the data in Table 8 suggest that reproductive longevity approximates physical longevity and that most adult females could produce offspring as long as they lived. The minimum breeding age is 4.5 years, but a female cub born into the population requires an average of 6.3 years to whelp her first litter. With an average reproductive cycle of 3.40 years and 2.24 average litter size, a 25-year old female would

Bear No.	Age Marked*	Repro. Years Prior to Pregnancy	Age at First Pregnancy	Age at First Recorded Pregnancy	Sequence of Cycles in Years				Repro. Period in Years	Age When Last Observed	Age When Last Litter was Produced
					1st	2nd	3rd	4th			
5	1.5	2	6.5	6.5	3	4			7	12.5	10.5
7	12.5	-	-	11.5	3	4	3		10	21.5	19.5
10	2.5	4	8.5	8.5	4	3			7	14.5	13.5
15	1.5	0	4.5	4.5	3	3	3		9	12.5	11.5
34	14.5	-	-	14.5	2	5	3		10	24.5	22.5
39	5.5	0	4.5	4.5	4	3	5		12	16.5	12.5
40	1.5	0	4.5	4.5	2	2	3		7	10.5	9.5
42	5.5	2	6.5	6.5	2	3	3	2	10	15.5	15.5
44	Adult	-	-	-	7				7	Min. 10.5	9.5
65	Adult	-	-	-	2	2	2		6	Min. 10.5	9.5
84	Adult	-	-	-	4	2			6	Min. 9.5	9.5
96	3.5	0	4.5	4.5	3	3	3		9	12.5	11.5
101	4.5	2	6.5	6.5	2	4	2		8	13.5	13.5
112	8.5	-	-	8.5	3	6			9	17.5	12.5
120	12.5	-	-	12.5	4	7			11	22.5	17.5
125	5.5	1	5.5	5.5	3	3	3	3(2)	12 (11)	15.5	15.5
128	10.5	-	-	10.5	3	2	3	2	10	19.5	19.5
140	8.5	-	-	10.5	5				5	12.5	11.5
141	1.5	1	5.5	5.5	3				3	7.5	6.5
144	0.5	0	4.5	4.5	4	2			6	9.5	9.5
150	4.5	0	4.5	4.5	4	5			9	12.5	9.5
160	Adult	-	-	-	6				6	Min. 9.5	5.5
163	1.5	0	4.5	4.5	2				2	5.5	5.5
172	11.5	-	-	11.5	3	2	3		8	19.5	17.5
173	2.5	0	4.5	4.5	3	2			5	8.5	8.5
175	10.5	-	-	10.5	3	2	3		8	17.5	16.5
175B	Adult	-	-	-	3	3			6	Min. 10.5	8.5
180	11.5	-	-	11.5	3				3	14.5	12.5
187	1.5	1	5.5	5.5	3				3	7.5	6.5
200	3.5	0	4.5	4.5	4				4	8.5	5.5

TOTALS 13 100 72 39 7 218 + 13 = 231

*Bears designated as "Adult" were assumed to be at least 4.5 years of age.

Table 8. Reproductive performance of 30 female grizzlies, 1959 - 1972.

experience 6 reproductive cycles and produce 13 cubs.

Sequence of Reproductive Cycles

We examined reproductive cycles to determine if any sequence or sequences for 30 females was more prevalent than others. The sequence of reproductive cycles varied greatly among individual females (Tables 8 and 9). For example, one female's first reproductive cycle was 3 years and her second, 4 years. Another female had a sequence of 3, 4, and then 3.

Among females with at least two reproductive cycles, cycle length consisted of 12 combinations: 6 occurred once, 4 were repeated, and 2 (3-3 and 3-2) occurred four times each.

Among females with 3 reproductive cycles, 9 combinations occurred. Seven occurred once, while 2 sequences (3-3-3 and 3-2-3) occurred three times each. Since (3-3 and 3-2) occurred four times each in two-cycle sequences, one would expect them to predominate, as they did, in three-cycle sequences. Whether these repetitive patterns have significance is unclear, but they definitely relate to physiological differences which are responses to such extrinsic factors as food, climate, and population density. Variations in both cycle length and litter size appear to be natural population-regulating mechanisms. However, Table 9 does not reveal a sequential correlation between cycle length and litter size, so compensatory processes may not be highly developed.

Length of Cycle Versus Cubs Produced

A Spearman Rank Correlation Coefficient (S.R.C.C.) was used to determine if length of reproductive cycle in years was related to number of cubs produced per cycle as shown by data in Table 10. No significant correlation

Bear No.	Sequence of Cycles in Years				Sequence of Litter Sizes				Cubs Produced/Year			
	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th
5	3	4			2	3			0.67	0.75		
7	3	4	3		3	3	2		1.00	0.75	0.67	
10	4	3			2	2			0.50	0.67		
15	3	3	3		2	1	2		0.67	0.33	0.67	
34	2	5	3		2	2	2		1.00	0.40	0.67	
39	4	3	5		2	3	2		0.50	1.00	0.40	
40	2	2	3		2	2	3		1.00	1.00	1.00	
42	2	3	3	2	2	2	2	2	1.00	0.67	0.67	1.00
44	7				2				0.29			
65	2	2	2		2	4	3		1.00	2.00	1.50	
84	4	2			3	2			0.75	1.00		
96	3	3	3		2	4	2		0.67	1.33	0.67	
101	2	4	2		1	1	2		0.50	0.25	1.00	
112	3	6			3	2			1.00	0.33		
120	4	7			2	2			0.50	0.29		
125	3	3	3	3	2	3	3	2	0.67	1.00	1.00	0.67
128	3	2	3	2	3	3	4	3	1.00	1.50	1.33	1.50
140	5				3				0.60			
141	3				2				0.67			
144	4	2			2	2			0.50	1.00		
150	4	5			3	2			0.75	0.40		
160	6				2				0.33			
163	2				2				1.00			
172	3	2	3		3	1	3		1.00	0.50	1.00	
173	3	2			2	1			0.67	0.50		
175	3	2	3		1	2	1		0.33	1.00	0.33	
175B	3	3			2	2			0.67	0.67		
180	3				3				1.00			
187	3				1				0.33			
200	4				2				0.50			
Σ	100	72	39	7	65	49	31	7				
$\bar{x}$	3.33	3.27	3.00	2.33	2.17	2.23	2.38	2.33	0.65	0.68	0.80	1.00

Table 9. Sequence of cycle lengths for 30 female grizzlies, 1959 - 1972.

	<u>2-Yr</u>	<u>3-Yr</u>	<u>4-Yr</u>	<u>5-Yr</u>	<u>6-Yr</u>	<u>7-Yr</u>
1.	2	2	2	3	2	2
2.	2	3	2	2	2	2
3.	2	2	3	2	$\Sigma = \frac{2}{4}$	$\Sigma = \frac{2}{4}$
4.	2	2	2	2	$\bar{x} = 2.0$	$\bar{x} = 2.0$
5.	1	3	2	$\Sigma = \frac{2}{9}$		
6.	2	2	3	$\bar{x} = 2.25$		
7.	2	3	2			
8.	4	2	3			
9.	2	3	3			
10.	3	2	1			
11.	2	1	$\Sigma = \frac{1}{23}$			
12.	1	2	$\bar{x} = 2.30$			
13.	1	3				
14.	2	1				
15.	3	2				
16.	2	1				
17.	2	3				
18.	3	2				
19.	$\Sigma = \frac{3}{38}$	4				
20.	$\bar{x} = 2.11$	3				
21.		2				
22.		2				
23.		2				
24.		2				
25.		3				
26.		2				
27.		2				
28.		3				
29.		4				
30.		3				
31.		1				
32.		2				
		$\Sigma = \frac{2}{74}$				
		$\bar{x} = 2.31$				

Table 10. Length of cycle versus number of cubs produced, 1959 - 1972.

between average length of a reproductive cycle and average number of cubs produced was shown. The "rho" value equaled +0.124, a statistically insignificant positive correlation.

EVALUATION OF PROCEDURAL BIAS ON RESULTS

To determine whether procedural biases were present in evaluations of reproductive cycle, reproductive rate and litter size, the results for these parameters were tested statistically.

Productivity Related to Age of Females

Ages of marked females varied from 0.5 to 14.5 years. Eleven of the 30 females were between 0.5 and 3.5 years, ten were 4.5 and 5.5, and nine were between 8.5 and 14.5 when marked. If productivity was dependent on age of the female, then the age composition of a sample could affect the values obtained for reproductive cycles and reproductive rates. This was tested by arranging data on number of litters and number of cubs produced by 28 females into one-year age groups (5.5 to 25.5 years of age). A S.R.C.C. was calculated to compare individual age of post-parturient females with number of cubs per litter. The "rho" value was -0.021, a statistically insignificant negative correlation.

Other correlation coefficients compared adult age-groups against number of cubs per litter. These tests determined whether females were more productive during certain periods of life. Grouping female grizzlies into six 3-year age categories (Table 11) and ranking them against numbers of cubs gave a "rho" value of +0.132. The six groups were then consolidated into 3 arbitrary age categories of young (5.5 - 9.5 years), prime (10.5 - 17.5) and old (18.5 - 22.5) bears. A S.R.C.C. calculation produced a "rho" value of +0.118 when age categories were ranked with number of cubs in

<u>Age Class</u>	<u>No. of Litters</u>	<u>No. of Cubs</u>	<u>Ave. No. of Cubs</u>	<u>Age Class</u>	<u>No. of Litters</u>	<u>No. of Cubs</u>	<u>Ave. No. of Cubs</u>
5½	13	28	2.2	14½	2	5	2.5
6½	4	6	1.5	15½	5	10	2.0
7½	5	11	2.2	16½	2	5	2.5
Total 5½-7½	22	45	2.0	Total 14½-16½	9	20	2.2
8½	4	8	2.0	17½	3	7	2.3
9½	11	26	2.4	18½	0	0	0.0
10½	1	3	3.0	19½	2	5	2.5
Total 8½-10½	16	37	2.3	Total 17½-19½	5	12	2.4
11½	4	8	2.0	20½	0	0	0.0
12½	6	15	2.5	21½	0	0	0.0
13½	3	6	2.0	22½	1	2	2.0
Total 11½-13½	13	29	2.2	Total 20½-22½	1	2	2.0

Table 11. Productivity of 28 female grizzlies related to age, 1959 - 1972.

litters. Neither of these "rho" values were statistically significant positive correlations. Therefore, we concluded that age of females in our sample did not appreciably affect litter size.

Variations in length of reproductive cycles for individual females, between different females, and variation in the sequential combinations of reproductive cycles (Table 8), indicated that a relationship might exist between a female's age and length of her reproductive cycle. A S.R.C.C. calculated to examine this relationship resulted in "rho" equal to +0.256. This level of positive correlation is not statistically significant. Correlation between the female's age at her last litter and the length of her last reproductive cycle was also found to be statistically insignificant. Because the coefficient of correlation was +0.025, we concluded that age of the females sampled caused no significant bias in our calculations of litter size, length of reproductive cycle or reproductive rate.

Immobilizations Related to Reproductive Rate

Female grizzlies were individually drugged to obtain reproductive and other types of information. Succinylcholine chloride and phencyclidine hydrochloride were used as immobilizing agents. Numbers of immobilizations per adult female ranged from 1-12 and from 2-17 for females initially captured as sub-adults.

To test the possibility that frequent use of drugs may have altered long-term productivity, we compared the number of immobilizations per adult female to the reproductive rate of each female and age of sub-adult females at their first litter. A correlation coefficient between number of immobilizations and reproductive rates of 12 adult females (Table 12) was not statistically significant ("rho" value of -0.332). A similar test for

Bear No.	Age Marked	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	Total	Age 1st Observed Litter	Repro. Rate
7	12.5	1	-	1	-	2	-	-	-	1	-	-	-	5	12.5	0.800
23	14.5	-	2	-	-	1	1	1	-	1	-	1	-	7	15.5	0.600
39	5.5	-	1	1	-	1	1	-	-	1	2	5	-	12	5.5	0.583
42	5.5	-	1	-	-	1	1	-	-	1	3	-	-	7	7.5	0.800
65	Adult	-	1	1	-	-	-	-	-	-	-	-	-	2	Min. 5.5	1.500
84	Adult	-	-	1	-	-	-	-	-	-	-	-	-	1	Min. 5.5	0.833
112	8.5	-	-	1	-	-	-	-	1	2	3	-	-	7	9.5	0.556
120	12.5	-	-	1	-	-	-	-	1	-	-	-	-	2	13.5	0.364
125	5.5	-	-	-	1	-	-	-	-	-	-	-	-	1	6.5	0.833
128	10.5	-	-	-	1	1	-	-	-	1	-	1	-	4	11.5	1.300
172	11.5	-	-	-	-	-	1	-	-	1	-	-	-	2	12.5	0.875
175	10.5	-	-	-	-	-	1	-	-	1	-	-	-	2	11.5	0.500
TOTALS		1	5	6	2	6	5	1	2	9	8	7	-	52		

Table 12. Number of immobilizations related to reproductive performance for 12 adult female grizzlies, 1959 - 1970.

14 sub-adult females (Table 13) yielded no significant correlation between number of immobilizations per female and reproductive rate ("rho" value of +0.345). A third S.R.C.C. indicated no significant correlation between number of immobilizations prior to age 5.5 and age of a female at first litter ("rho" value of +0.496). We concluded that drugs did not significantly alter reproduction and did not bias the data values.

Food Supply Related to Reproductive Rates

Both intrinsic and extrinsic factors affect reproductive rates but are difficult to isolate and analyze. Lack of comparative data precludes thorough evaluation of whether long-established open pit garbage dumps affected the reproductive rate of female grizzlies or altered the carrying capacity of the pristine habitat. However, the abrupt closing of garbage dumps in Yellowstone during 1969 and 1970 did stress the population and appears to have lowered the reproductive rate (Craighead et al., 1974). The feeding habits of most females were observed in detail during the time reproductive histories were recorded. We cannot, at this time, show any statistical significance between food supply and reproductive rates of specific females (Craighead et al., in prep.). However, a drop in annual reproduction during the 1970-73 period probably relates to a marked decrease in food supply associated with the abrupt closing of open pit garbage dumps (Craighead et al., 1974). Studies on other animals have shown that a decrease in nutritional level can affect reproductive success (Cheatum and Severinghaus, 1950; Buechner, 1955; Knowlton, 1972). Jonkel and Cowan (1971) presented inconclusive data suggesting an increased black bear reproductive rate coinciding with an increase in food.

<u>Bear No.</u>	<u>Age Marked</u>	<u>1959</u>	<u>1960</u>	<u>1961</u>	<u>1962</u>	<u>1963</u>	<u>1964</u>	<u>1965</u>	<u>1966</u>	<u>1967</u>	<u>1968</u>	<u>1969</u>	<u>1970</u>	<u>Total</u>	<u>Age 1st Litter</u>	<u>Repro. Rate</u>
5	1.5	1	1	1	-	-	-	1	-	1	1	-	-	6	7.5	0.714
6	0.5	1	2	2	2	-	2	1	-	-	-	-	-	10	7.5	Killed-Blastocysts Recovered
10	2.5	1	-	1	-	-	1	-	-	1	-	-	-	4	9.5	0.571
15	1.5	1	-	1	-	-	-	-	-	-	-	-	-	2	5.5	0.556
29	0.5	1	-	2	-	-	-	1	-	-	-	-	-	4	6.5	0.250
40	1.5	-	2	1	1	1	2	2	2	2	3	1	-	17	5.5	1.000
81	2.5	-	-	1	-	-	-	1	-	-	-	-	1	3	6.5	0.250
96	3.5	-	-	1	1	3	-	-	-	1	-	-	-	6	5.5	0.889
101	4.5	-	-	1	-	-	1	-	-	3	2	-	-	7	7.5	0.500
200	3.5	-	-	-	-	-	-	1	-	1	1	-	-	3	5.5	0.500
187	1.5	-	-	-	-	-	1	1	1	1	2	-	-	6	6.5	0.250
163	1.5	-	-	-	-	1	-	-	-	3	-	-	-	4	5.5	1.000
144	0.5	-	-	-	-	1	-	1	4	-	-	1	1	8	5.5	0.667
150	4.5	-	-	-	-	2	1	-	-	1	-	-	-	4	9.5	0.556
173	2.5	-	-	-	-	-	1	-	-	1	-	-	-	2	5.5	0.600
TOTALS		5	5	11	4	8	9	9	7	15	9	2	2	86		

Table 13. Number of immobilizations related to reproductive performance for 15 sub-adult female grizzlies, 1959 - 1970.

The major food types used by grizzlies in the Yellowstone ecosystem were green vegetation, roots and tubers, berries, pine nuts, small rodents, large herbivores and garbage. Relatively slight annual fluctuation occurred in the availability of green vegetation, roots, tubers, and garbage while great variation occurred annually in the other major foods. The garbage available to bears helped stabilize the nutritional level of the population and, in turn, should have elevated the reproductive rates. On the other hand, density-dependent factors such as infanticide due to male aggressiveness and hormonal activity regulating estrus, and thereby the intervals between litters, constituted intrinsic factors that may have offset the favorable nutritional effects by decreasing the reproductive rates. Infanticide was low (eight records) and not a significant factor. The great variability in the reproductive cycle sequences could have been an important factor in regulating reproduction, but it will be difficult to draw conclusions from these data until similar information from other populations is obtained and norms established.

We suspect that the average reproductive rate of 0.658 for 30 females may be optimum for the Yellowstone population. We believe the decrease in available food that occurred with the abrupt closing of the open pit garbage dumps will continue to exert a long-term damping effect on reproduction. Other regulatory processes yet unmeasured may eventually mitigate the decreased food supply. Future species management, however, should not be based on unproven assumptions. Present evidence suggests that in the near future, a lowered reproductive rate associated with the decreased food source is more probable than a rising rate attributable to a decrease in population density.

DISCUSSION

Reproductive parameters of Yellowstone grizzlies have been shown to be highly variable. Ages at first pregnancy ranged from 4.5 to 8.5 years, reproductive cycles from 2 to 7 years, litters from 1 to 4 cubs and reproductive rates from 0.286 to 1.500 for individual females studied. Flexibility of these biological parameters should presumably enable the species to adapt to changing environmental conditions and compensate for population growth and decline. However, characteristics of reproductive parameters for a long-lived species exhibiting delayed maturity suggest that compensatory reproductive processes (increases in litter size, decreases in length of reproductive cycle, and/or higher survivorship rates for sub-adult bears) would be slow. The grizzly bear throughout evolutionary time has had few natural enemies, partially explaining the relatively low reproductive rate. In modern times, man has the capability of inflicting rapid and heavy mortality. There is no scientific evidence that the grizzly bear has the capacity to compensate for high mortality rates inflicted by man. On the contrary, Craighead et al. (1974) have shown that the Yellowstone grizzly cannot sustain a high death rate for even a short period of time without endangering population integrity. Any abnormal mortality such as excessive control by man or heavy kills by hunters, or both, should be viewed with concern because it can rapidly cause an irreversible decline in population size. The historic decline and extinction of the grizzly bear in the western United States has probably occurred because of the species' low reproductive rate and its inability to cope with man-induced mortality. The grizzly has been able to survive only in large national parks and national forest wilderness areas because these spacious habitats

have, until recently, insulated the species from excessive deaths. If threatened with high mortality rates, the grizzly will face extinction just as surely as it did in California some 50 years ago.

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We extend special thanks and credit to Dr. Maurice Hornocker, Mr. Jay Sumner, Dr. Robert Ruff, and Dr. Jerry McGahan who, first as students then as research associates, worked closely with us in the field and in the laboratory. With their help, it was possible to maintain the continuity of research effort so essential for a long-term population study. The senior author is particularly indebted to Jay Sumner, whose loyalty and hard work enabled us to continue the study during 1971, 1972 and 1973 under extremely adverse conditions. Dr. Bart O'Gara cheerfully accepted extra duties at the Montana Cooperative Wildlife Research Unit to provide the senior author with time to write. We also wish to thank Harry Reynolds, Jr., Harry Reynolds III, James Claar, and Lance, Derek, Charles and Karen Craighead for their help.

The support and encouragement of many other persons made this investigation possible. Thanks are extended to Mr. Horace Albright, an outstanding Park Service Director; Mr. Lemuel Garrison, and other personnel of Yellowstone National Park; Dr. Melvin M. Payne, President of the National Geographic Society; Dr. Vincent J. Schaefer, Director, Atmospheric Science Research Center, State University of New York at Albany; Dr. Laurence M. Gould, past president AAAS; and Dr. George Jacobs, NASA. Personnel of the Montana, Idaho, and Wyoming Fish and Game Departments helped to locate and verify known grizzly bear kills.

Mr. Frank Goodyear, Mr. Donald Ozmun, and Mr. Charles Pihl made annual personal donations to our research effort that were invaluable in helping us to maintain continuity in seeking solutions to a complex resource problem.

For professional help and advice in statistical problems, population modeling and programming, we are grateful to Dr. Mark Behan, Dr. Frank Munshower, Dr. William Pierce, Dr. Don Loftsgaarden, Dr. Dave Firmage and Mr. John Mitchell.

MONTANA COOPERATIVE WILDLIFE RESEARCH UNIT

UNIVERSITY OF MONTANA
MONTANA FISH AND GAME COMMISSION
WILDLIFE MANAGEMENT INSTITUTE
FISH AND WILDLIFE SERVICE, UNITED STATES DEPARTMENT OF THE INTERIOR

UNIVERSITY OF MONTANA
MISSOULA, MONTANA 59801

16 May 1975

Dr. Frank C. Craighead, Jr.
P.O. Box 156
Moose, Wyoming 83012

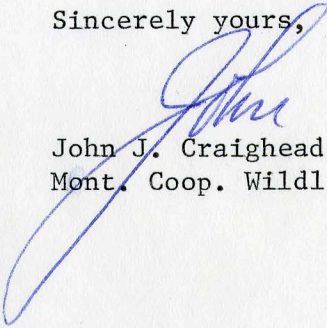
Dear Frank:

The Ramada Snow King Inn sent me a letter indicating the facilities that would be available to our Bear Research and Management Symposium. They certainly look good to me, and I think we should hold out for having the conference in Jackson Hole. Those attempting to switch it to Kalispell are doing it for purely political reasons.

Enclosed is a copy of the reproductive paper as I modified it for publication in the Transactions of the Bear Symposium. If you want me to look over the range paper before sending it in, I will be glad to do so but, in any event, please send me a final copy.

Regards.

Sincerely yours,



John J. Craighead, Leader
Mont. Coop. Wildl. Res. Unit

JJC:nlh
Enclosure

Dear John

I am enclosing a copy of the grizzly bear range and movement paper. I rushed a copy of this off to Jack Lentfer as it was already overdue. This may be the last opportunity to publish on this radio range and movement data although we still have some not yet treated. For this reason I would very much oppose further shortening of the paper. I think that it is essential to include a short section on management as the people experienced with the subject are those best qualified to make management recommendations. If we do not I am not just sure who will.

? I have put only myself as author although originally I had both of us. You insisted that I remove your name and I did so and told you that I would put it back but only when and if I heard from you to the contrary. So far I have not received any correspondence that would indicate you have changed your views.

We had an unusually good meeting in Easton Md and it turned out that we were the only ones who had developed a ~~RAMS~~ ^{RAMS} transmitter and yet every one of the user groups need this equipment in order to make use of the nimbus satellite. I think our RAMS transmitter report will be ^{Appended} attended to the conference report. I had some ^{interesting} ~~good~~ discussions with Jacobs, Cote, and others. Buechner is in the hospital in a critical condition.

Regards

**MAN'S population
predicament**

population

A PUBLICATION OF THE
POPULATION REFERENCE BUREAU, INC.

bulletin

THE TWENTY-FIRST CENTURY

The often-sounded warning that high rates of population growth constitute one of mankind's two or three most critical problems has created a credibility gap. The possible dire consequences of overpopulation have been repeated so often that further repetition sounds to many people like the prediction of religious fanatics that the world will end abruptly on a specific date. On the day after the world's last day, the doomsayers awake feeling embarrassingly healthy. Similarly, the more years that pass without cataclysmic effects from rapid growth in world population, the more people may doubt the sanity or accuracy or wisdom of population Cassandras.

But there is an important difference. The analysts who seek to interpret the meaning of the growing tidal wave of humanity start with enough known facts to make their stark predictions more than wild guesses. They do not know precisely when or how the consequences of overpopulation will reach catastrophic proportions, but they do know that we are in an extremely abnormal period of growth, and that it is physically impossible for the present 2 percent growth rate to be continued for as much as two centuries into the future. They know some 37 percent of the world's population is under 15 years of age, that unless death rates rise sharply or fertility falls to or below two children per woman on the average all over the world in the next two decades, the population of the world during the twenty-first century is likely to reach at least 7 billion and probably nearer 10 billion. It could go higher. And they can foresee that going from our present 3.7 billion to 7-10 billion will make the solution of other problems enormously more difficult.

When and how will births and deaths be brought into balance? It is now predictable with a substantial degree of probability that

the balance will come about during the twenty-first century. How it will occur is far less predictable.

This *Bulletin* attempts to help bridge the credibility gap by illuminating man's population predicament in words and graphics. It attempts to interpret the origins of the population explosion, report briefly on the present state of affairs, and then present three models out of many possible population trends in the twenty-first century. Such modeling, we believe, is an aid to careful and critical thinking.

The twenty-first century may seem a long way off, but it is not. We are closer to its beginning than to the beginning of World War II; even more striking, children being born now who live 60 years or more will live most of their lives in the next century. The twenty-first century is not only real and relevant; it is far more important to our own children and grandchildren than the twentieth century.

Solving the population problem will not be a panacea for mankind. Problems of raising the living standards of the poor—who constitute a majority of mankind—improving race relations, reducing tensions between nations and reducing nationalism itself, and controlling the pollution of our environment are likewise high on the human agenda and cannot be overcome merely by slowing or even stopping population growth. But all of these problems would be alleviated by sharply diminishing and eventually bringing an end to further population growth. And no prospect exists for a stable international society until and unless world population growth is brought under control.

Rufus E. Miles, Jr., *Editor*

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MAN'S POPULATION PREDICAMENT

THE ORIGIN AND MEANING OF THE POPULATION EXPLOSION

The human population of the earth probably passed the 3.6 billion point in 1970, increasing by some 70-75 million each year. We say "probably" because current census data for many countries are nonexistent, unavailable or unreliable. At the current 2 percent rate of increase, every three years the world population grows by a number greater than the 207 million people now living in the United States. Every five days we add another million people to our human population.

When one of the worst disasters of the twentieth century occurred in East Pakistan in the fall of 1970, an

estimated half million people were drowned by a great tidal wave. Yet it took only 35-40 days for Pakistan's population to exceed the number it had reached the day before the disaster, assuming continuation of the growth rates of the recent past.

Another way to look at the population explosion is in the perspective of man's development as a species. During the hundreds of thousands of years of the Old Stone Age when man was a hunter and a food gatherer, the world population probably never exceeded 10 million. Sometime between 8000 B.C. and 6000 B.C. man learned how to grow his

own food and create settlements and eventually cities. The shift from food gathering to food growing was a momentous change. Man found he could support vastly larger numbers by settling down and cultivating the soil and planting seeds. In the next 6,000-8,000 years, man's numbers increased to about 200-300 million and by 1650 A.D. reached an estimated 500 million.

The increase from about 10 million at the beginning of the agricultural era to 500 million about 8000-10,000 years later—a fiftyfold increase—was a "population explosion" in itself. This term, however, has been applied with greater reason to the even more rapid gain which has occurred in the last three centuries. In the 200 years from 1650 to 1850, the world population doubled and reached its first billion. In the next 80 years, it doubled again, and by 1975, at present rates, it will double again to a total of 4 billion. By the year 2000 it will exceed 6 billion and possibly approach 7 billion unless there is a major reduction in birth rates or a major increase in death rates. At present rates we will add 1 billion people in a mere dozen years—a number more than the total population of the earth at the time Thomas Malthus stimulated the world to think about population a century and a half ago.

Figure 1 (p. 4) shows the change in the tempo of increase which began about 1650. As is evident by the gap between birth and death rates illustrated in the graph (p. 6), the growth is bound to continue, particularly in Asia, Africa and Latin America. The graph (p. 7) illustrates the population in various regions in 1965, and where it is likely to be in 1985. How much longer can this

steep curve keep climbing upward? And what is to stop the upward climb?

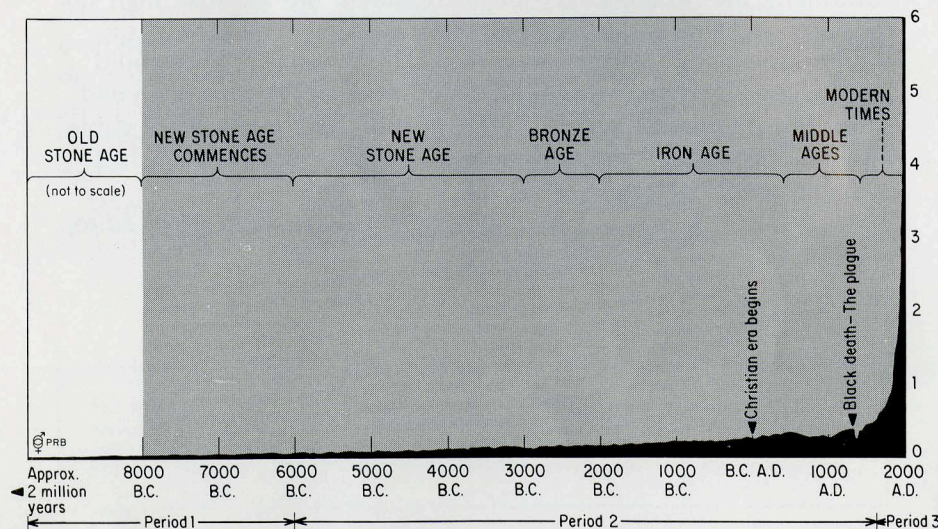
Neither the earth nor man can stand many more doublings of his population. From the "time of Adam and Eve" until now, man's population has doubled 31 times. If it were to double another 16 times, there would be one square yard for every man, woman and child on earth. This cannot happen. The human population of the globe will stop growing long before 16 more doublings or even 8 more doublings, not for sheer want of space but for want of food, water and other natural resources and possibly because of environmental pollution. It is to be hoped that man's intelligence will establish other effective limits, having to do with the quality of life, before resources run out or pollution becomes literally intolerable, but this is by no means certain.

The question arises: How and when will the growth in man's numbers come to an end? And when it does come to an end, will world population level off and stabilize or, having overshoot the sustaining capacity of the earth, will it then fall back? Nobody really knows the answers to these questions. We must try to find them, however—and we must also try to understand what has caused man's population to spurt ahead so rapidly.

What has happened since 1650 to boost the world's population so high? The answer seems to be that we are witnessing a compound effect from many significant causes. In the space of a few centuries a vast pair of continents was filled up, an industrial and technological revolution swept the world and civilization became complex, rapidly urbanizing,

Figure 1:

POPULATION THROUGH HISTORY

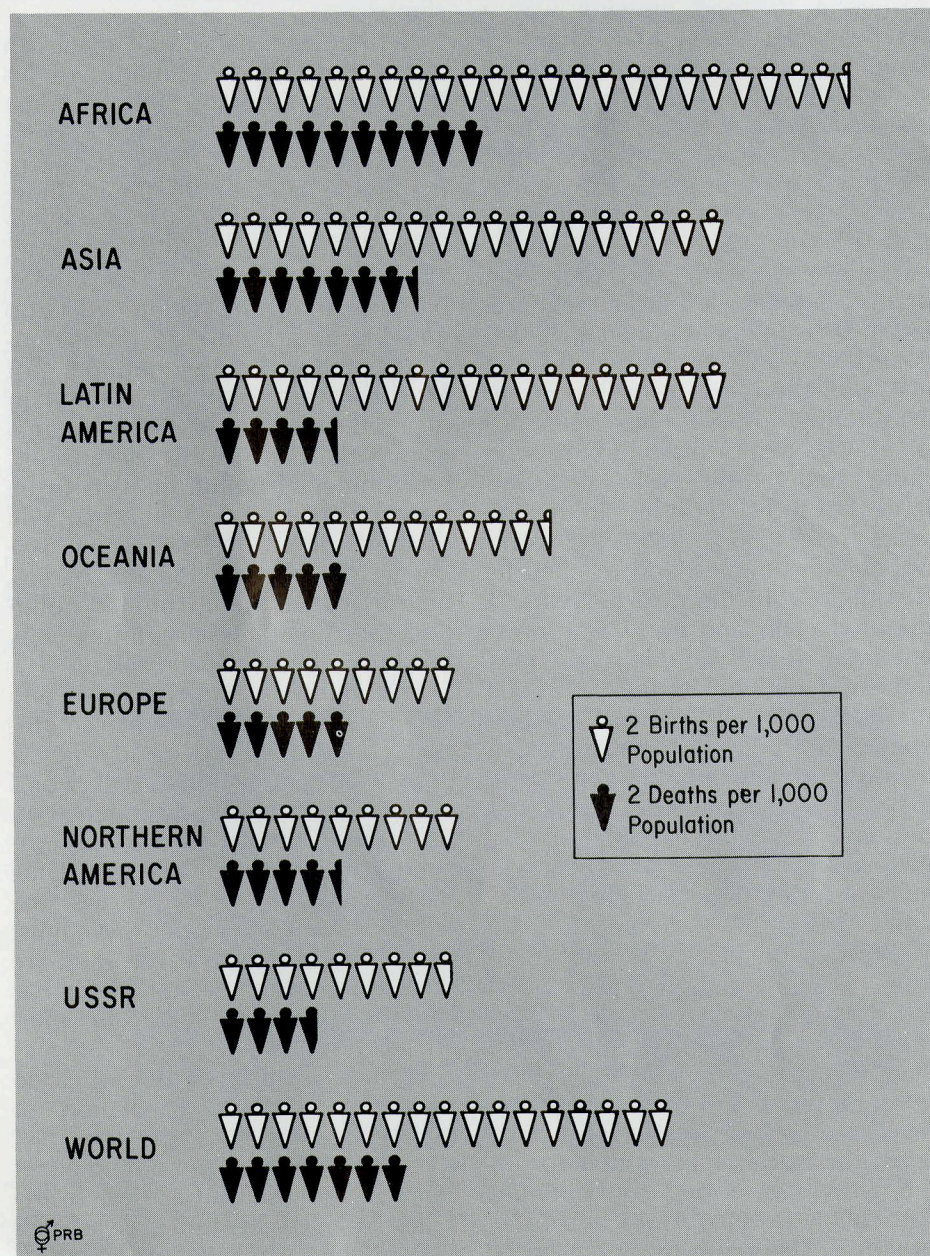


Source: Population Reference Bureau, Inc. "How Many People Have Ever Lived on Earth?", *Population Bulletin*, Vol. XVIII, No. 1.

Man's numbers reached a half billion by the year 1650 A.D.; at present rates population is increasing by one billion in a dozen years.

Figure 2:

PRESENT BIRTH AND DEATH RATES, BY AREA



Worldwide, for each thousand persons there are 20 more births than deaths a year. The rate is higher in Latin America, Africa and Asia.

interrelated and bent on rapid increases in consumption of all kinds of manufactured products. The effects of these changes on world population are analyzed in the following sections of this *Bulletin*.

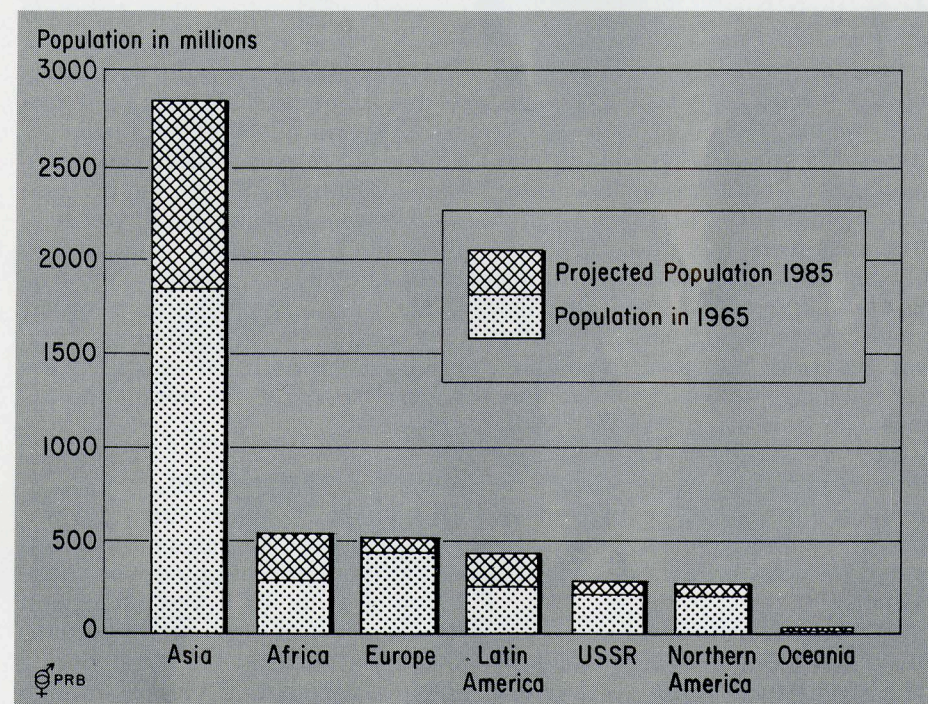
The filling up of the Americas

Prior to what has usually been referred to as the "opening" of the Western Hemisphere, its population

1 million, and the population of Mexico and Central America, South America and the Caribbean Islands was not more than 12-14 million. The European conquest of these two great continents led very rapidly to their colonization, the cutting of forests, the development of farms and the most rapid growth in population in the recorded history of mankind. In three and a half cen-

Figure 3:

PROJECTED POPULATION GROWTH, BY AREA, 1965-1985



Percentage growth rates in Latin America and Africa are the highest, but Asia's greater population means a faster increase in numbers.

was low compared with all other major continents except Australia. It has been estimated that in the year 1600 the population of Northern America—north of what is now the Mexican border—was only about

the population of what is now the United States and Canada has grown from about 1 million to more than 225 million. During the period of most rapid growth the population doubled every 25 years. This rate

has slowed down very considerably during the twentieth century, but it is noteworthy that until the United States began its rapid industrialization in the second half of the nineteenth century, its rate of increase—even excluding immigration—was extraordinarily high.

Land—millions of acres of it—with rich topsoil was available to the ambitious men and women who crossed the Atlantic. They did not need to think in terms of limiting their families, as their European parents and grandparents often had, because of the shortage of good land for farming. Quite the contrary. Big families were looked on as assets by most American farm families during the eighteenth, nineteenth and even early twentieth centuries. Rural birth rates were therefore considerably higher in the Americas during this era of very rapid expansion than in Western Europe. This illustrates well the principle that population may expand rapidly when the factors which have previously held fertility growth in check suddenly become more elastic. The effect is even more pronounced when the relaxation of fertility checks is accompanied or followed by a decrease in mortality.

Latin America's increase was slower than Northern America's until the twentieth century, when it picked up speed and passed Northern America's rate of gain and also pushed ahead in absolute numbers. In recent years, Latin America has had the world's most rapid rate of growth. Asia, with a vastly larger population, adds many more people each year but has a slower rate of increase.

Figure 4 (p. 9) shows the absolute growth of the population of the

earth from 1000 A.D. to 2000 A.D., with the proportion of the total accounted for by the major continental masses. The chart shows the Americas' expanding share of the world total: from 3 percent in 1600, to 9 percent in 1900, to 14 percent in 1970, to the prospect of 14.5 percent in the year 2000.

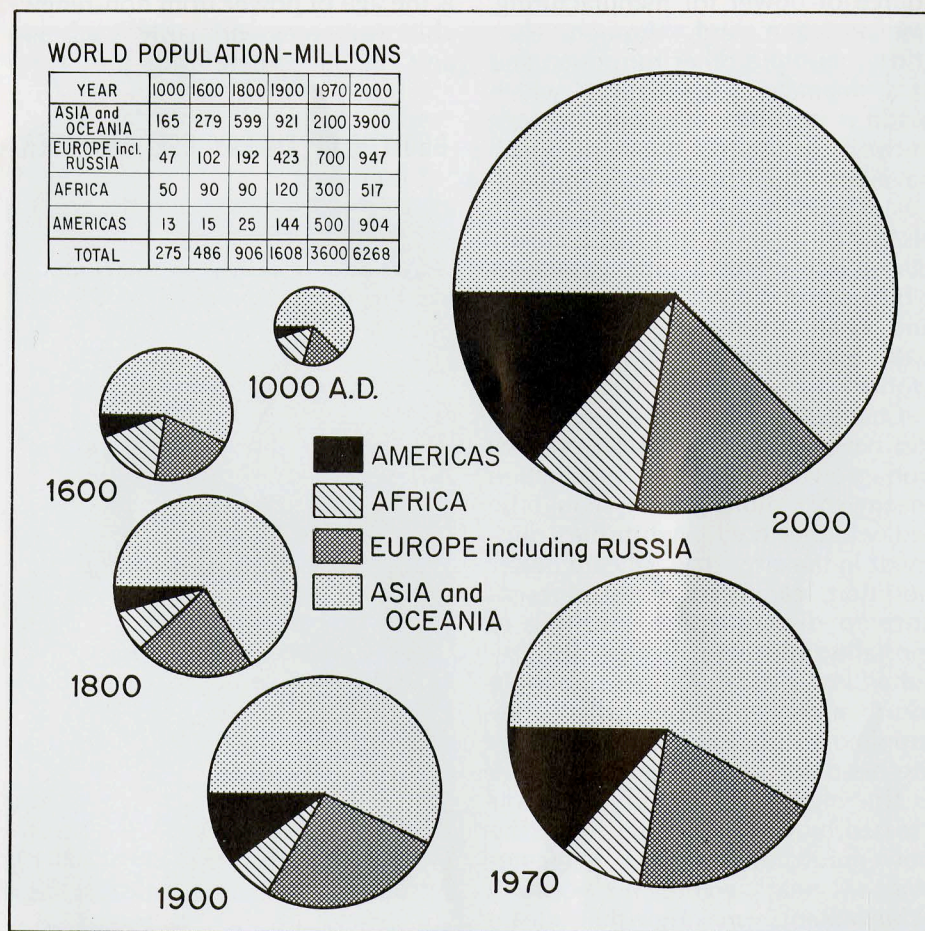
In the last three and a half centuries, the two American continents have added nearly as many people as the total population of the earth was in 1600 when the Americas began to be colonized. What the world population would have been if the Americas had not been discovered and filled up we can never know. It seems probable, however, that it is substantially greater because of the opening and exploitation of these two continents, primarily by Europeans. Therefore, although Asia today is numerically far more important, filling up the Americas with people must be listed as one of the basic elements in the population explosion.

The great transformation

The filling up of the Americas was but one aspect, though a momentous one from the point of view of population growth, of a vast change in the social and economic patterns that took place in the West during the nineteenth and early twentieth centuries. The character of Western civilization was transformed from a basically rural, agrarian society to a predominantly urban, industrial one. It was in the context of this industrial revolution that the present patterns of fertility and mortality in the West were formed. And, as will be shown in the next section, the population explosion in the rest of the world came largely as a result of the

Figure 4:

ONE THOUSAND YEARS OF POPULATION GROWTH



Sources: Population Reference Bureau, Inc. 1970 World Population Data Sheet. April 1970.

Population Reference Bureau. "A Thousand Years of World Population Growth" [wall chart], 1960.

The Americas held 3 percent of the world's population before Columbus; by 1970 the area's share of a much bigger pie was 14 percent.

sudden importation of technology into agrarian nations without the corresponding introduction of the economic and social changes that took place in the West during the industrial revolution.

The main features of the great transformation included: 1) an expansion of agriculture, both in terms

of the amount of land cultivated, especially in America, and in the productivity of agricultural workers, first as a result of mechanization, then fertilization and finally genetic improvement; 2) a growing trend toward urbanization, as agricultural changes made it possible to support more people with a smaller propor-

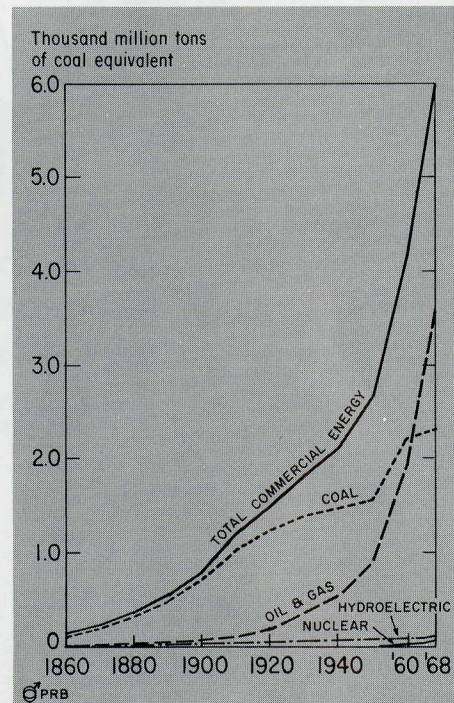
tion of farm labor; 3) a revolution in the use of coal and later oil as a source of power for manufacturing, transportation and, through electricity, multiple other purposes; and 4) a "managerial revolution" which made it possible to sustain the vast network of interrelationships which have been built up by the complexities of modern industrial civilization. Not all of these factors had a clearly discernible effect on the growth of world population in the last century and a half, but together they form a pattern which makes up the modern world.

Changes in agriculture, of course, did have a direct effect on population growth. Increased production meant that more people could be fed, whether they lived in the country or in the city. It also meant better nutrition, leading to increased resistance to disease and a lowering of mortality. But the change also resulted in a greater number of people in urban concentrations, where they supplied a labor market for the growing needs of expanding industry.

The market for urban labor was created by what might be called the power revolution. Prior to James Watt's great eighteenth century achievement, making the steam engine economical, the kinds of power used by man for all his purposes were biologically renewable ones—human labor, domestic animals and wood. Water wheels and windmills and the sails of ships were

widely used but they were secondary forms of power. The modern age is the age of power from non-renewable resources, primarily coal, gas and oil. Beginning with the steam

Figure 5:
GROWTH OF ENERGY USE, 1860-1968



Sources: Political and Economic Planning. *World Population and Resources*. London: George Allen and Unwin, Ltd., 1964.
United Nations. *World Energy Supplies*. ST/Stat/Series J. New York: Issues for 1958 (#1), 1960 (#3) and 1970 (#13).

World use of coal, oil and gas has boomed in a single century.

Sources: United Nations. *United Nations Demographic Yearbook*. New York: United Nations, issues for 1963 and 1964.

Herrick, Bruce H. *Urban Migration and Economic Development in Chile*. Cambridge, Massachusetts: M.I.T. Press, 1965.

Population Reference Bureau, Inc. "The World's Great Cities: Evolution or Devolution?", *Population Bulletin*, Vol. XVI, No. 6, 1960.

Urbanization (right) has been a part of the great industrial transformation.

Figure 6:

PERCENT LIVING IN CITIES OVER 20,000

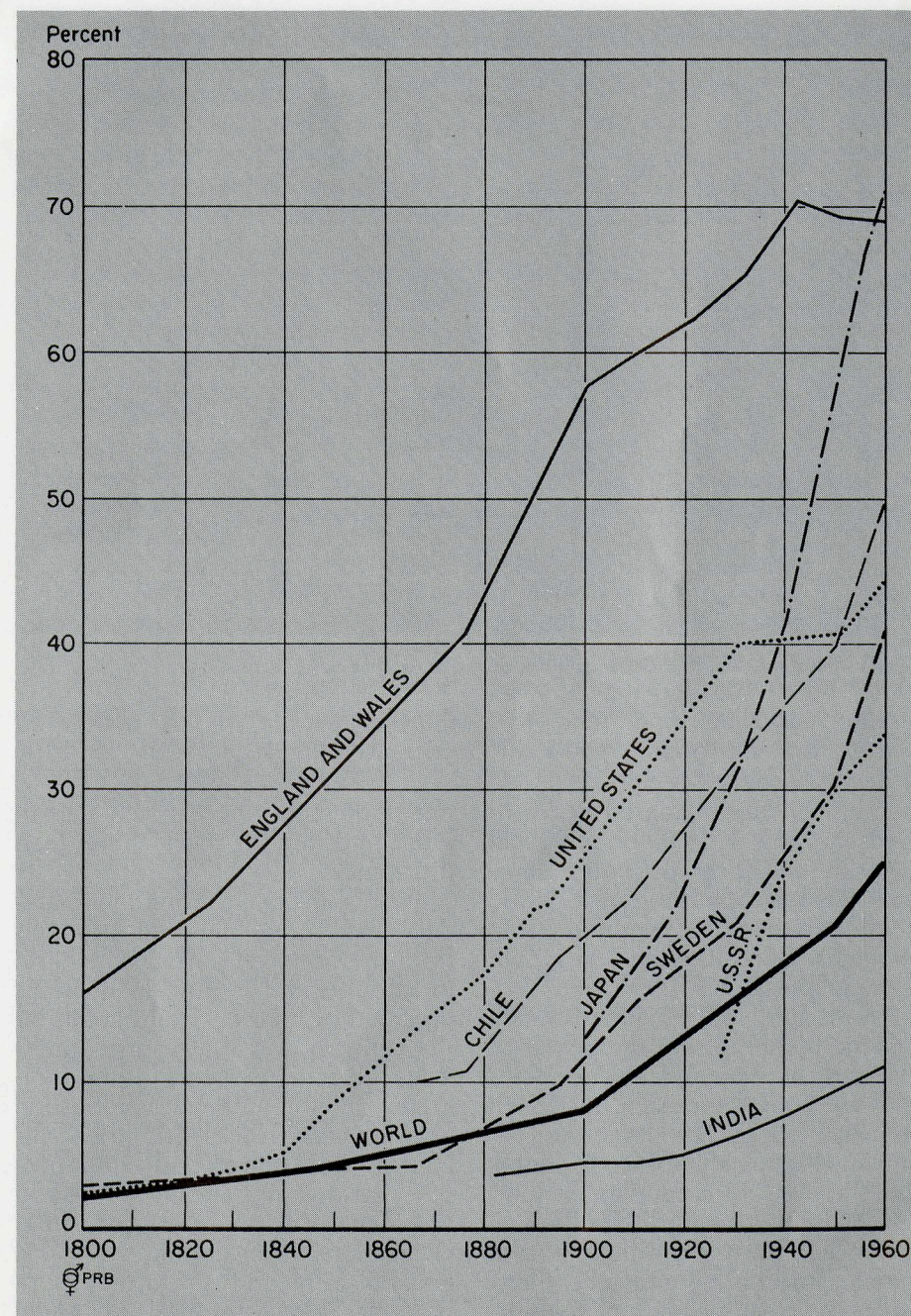
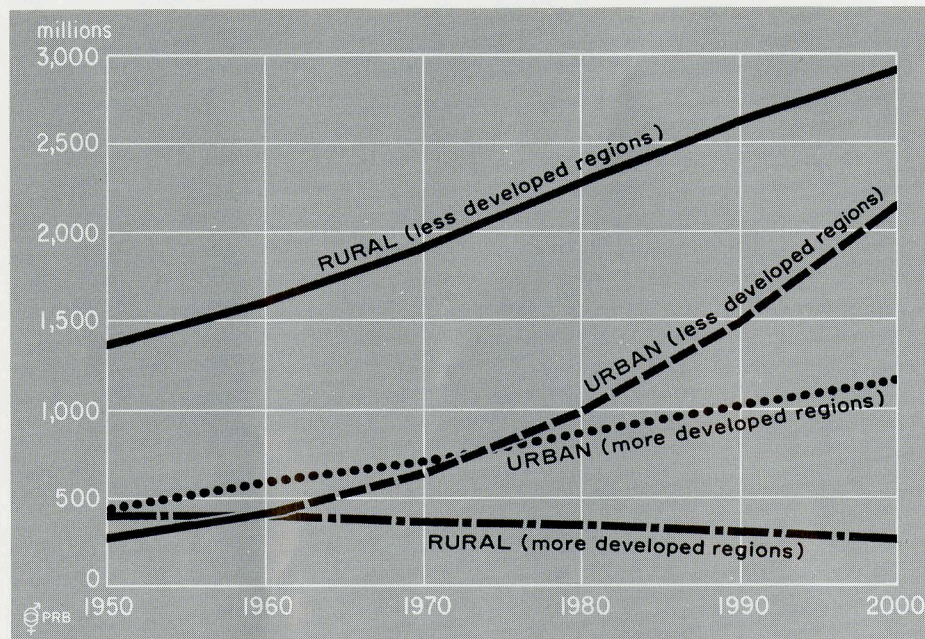


Figure 7:

RURAL AND URBAN POPULATION GROWTH, ESTIMATED



Source: United Nations. *A Concise Summary of the World Population Situation in 1970*. New York: United Nations, 1971.

By the year 2000 more than 40 percent of people in less developed regions will be urban dwellers, United Nations projections indicate.

engine, man has increased his command of power at a phenomenal rate. In the two centuries since Watt's steam engine began to work, the spurt in the use of non-renewable power has been meteoric, as shown in the graph (p. 10).

Power, and the machinery made possible by harnessing the power of coal and oil, have led to one major step after another, each of which has expanded—at least temporarily—mankind's capacity to feed, clothe, house and educate ever larger numbers of human beings. Non-human power led to the development of complex machinery and technology which could supply various material

needs of man with far less human effort and in a far shorter time than previously.

Steamships could bring raw materials and return finished products from the remotest parts of the earth in amounts and in time spans never dreamed of before. Trains could do the same on land at even faster rates. When electricity came along, followed by the internal combustion engine, cars, trucks and then airplanes, there developed cities of a size that dwarfed ancient Rome and the other seats of empires of earlier civilizations. Megalopolises became economically and technically supportable. Masses of humanity could

live without being anywhere near the sources of their food and clothing and the material with which their homes were built. Although this did not change man's dependence on agriculture and natural resources, it moved the sources of his sustenance out of sight, often to distant continents.

The degree to which urbanization has accompanied the industrial revolution and the enormous increase in productivity is evident from Figure 6 (p. 11). And it is the view of analysts that this trend will continue. The United Nations sees an acceleration of urbanization in the less developed regions for the balance of this century. (See Figure 7.)

The industrial revolution and the worldwide trend toward urbanization has been made possible by managerial and political skills that have so far managed to hold the incredibly complex system together. Sustaining the network of interrelationships of a world population of more than 3.7 billion has been taken for granted as a function which intelligent men ought easily to be able to do. It should, in fact, be regarded as a fantastic managerial feat. Without a quantum jump in management expertise in the last two centuries, and particularly in the twentieth century, the world would be in utter chaos and the population would not still be rising.

The medical-public health revolution

Industrialization, urbanization and the opening up of the Americas changed the basic patterns of civilization in much of the world during the nineteenth and early twentieth century. These changes were accompanied by a great expansion of scientific knowledge and technology,

including a revolution in the understanding, treatment and prevention of disease.

The fruits of this revolution have had a profound impact on population growth. As the new knowledge began to be applied, starting in the nineteenth century, mortality in Western Europe and the United States dropped significantly. A century later, after the scientific and technological advances accompanying World War II, the widespread application within the underdeveloped countries of DDT, immunization and other products of modern medicine produced an even more abrupt drop in mortality. The effect, unaccompanied this time by any significant reduction in birth rates, has been an explosive growth in world population.

Besides the effects of better nutrition on resistance to disease, already noted, the main components of the medical-public health revolution were a general approach toward cleanliness and purifying food and water, and the conquest of specific infectious diseases which had long plagued man. Although public hygiene had been the concern of communities for several centuries, it was not until 1850 that the need to separate water supplies from sewage was firmly established, and medicine gradually reached the point where more people were cured by treatment than were killed by pre-antiseptic conditions. In the last half of the century, and on into the present one, the causative factors of a host of killers, including plague, yellow fever, cholera, typhus, amoebic and bacillary dysentery, tuberculosis and malaria were identified; and the means of controlling them developed. For some diseases, notably

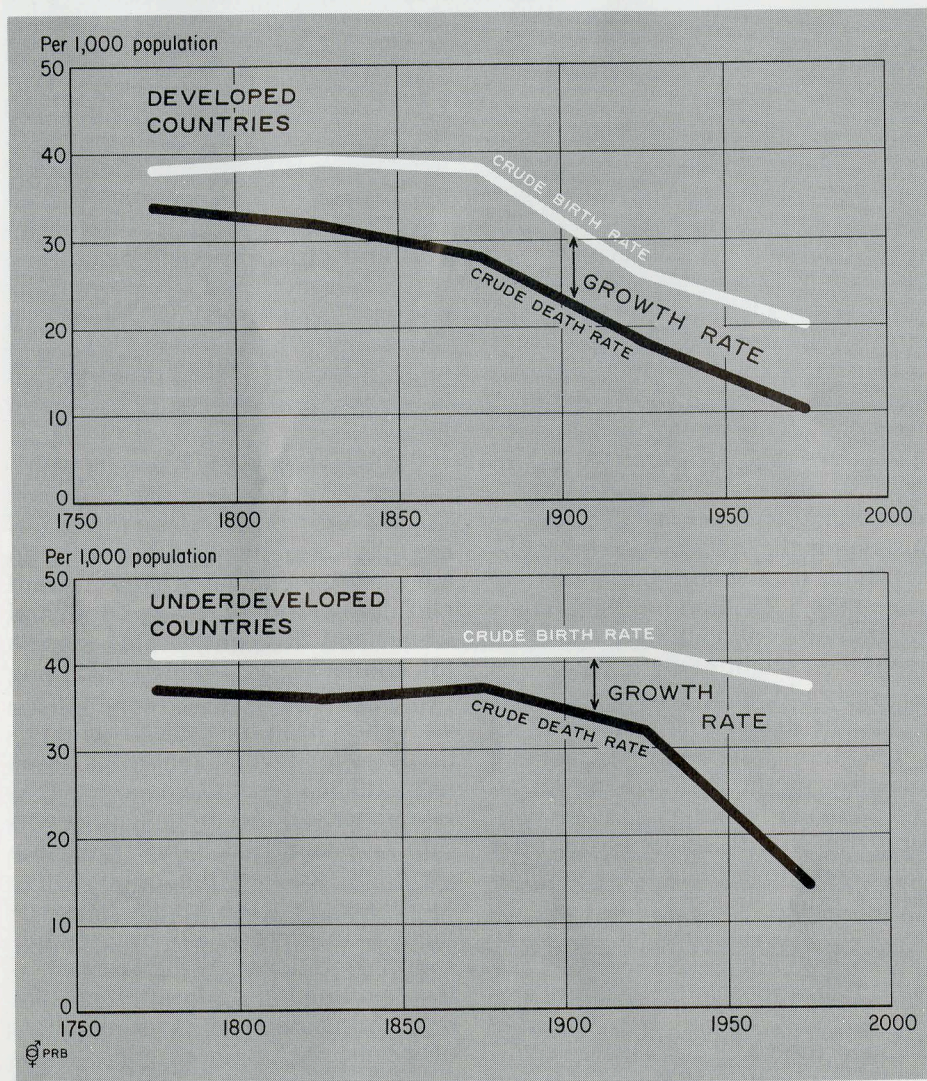
malaria, effective control had to wait until after World War II.

Starting in the 1800s mortality rates began to drop in countries

undergoing industrialization. In the 1840s in several Western European countries, data indicate that only about 85 percent of those born sur-

Figure 8:

ESTIMATED BIRTH AND DEATH RATES, 1770-1970



Source: United Nations. *A Concise Summary of the World Population Situation in 1970*. New York: United Nations, 1971.

In developed countries, decreased mortality was accompanied by dropping fertility; mortality drop was abrupt in underdeveloped countries.

vived the first year of life and about 65 percent lived to age 15. A century later, close to 96 percent survived the first year, and about 75 percent lived to age 60. It is estimated that the mortality rate in the more developed regions dropped from 28 per 1,000 in 1850 to 15 in 1950.

Much of this decline in mortality reflected the greater survival of infants. In Sweden, for example, at the beginning of the nineteenth century about one child in five did not survive the first year. This infant mortality rate dropped gradually throughout the century, and by 1900 it was about one in ten. It then declined more rapidly, to 21 per 1,000 live births by 1950 and about 15 by 1962, a decline of about 90 percent in 150 years. The decline was similar in other Western countries.

Thus, the three ancient scourges of man were brought under varying degrees of control. Famine was vastly reduced, pestilence was almost equally controlled,* and only war and accidents remained as a lessened but still significant cause of untimely mortality. With the near elimination of most serious infectious diseases, the causes of mortality shifted to the chronic and stress diseases, such as cancer and heart disease, which strike more at the older sectors of the population.

The situation was different in the underdeveloped world. Until the end of World War II, there was a gradual decline in mortality, probably due in part to better control of epidemic diseases including plague, smallpox and cholera, but estimates indicate that death rates were still

* Influenza remains stubbornly recalcitrant, erupting every few years in a variant, immunity-resistant form that sweeps the world in pandemics reminiscent of the old days of plague and cholera. Although not a violent killer in itself, it causes many deaths from complications such as pneumonia.

close to 30 per 1,000 in the late 1940s.

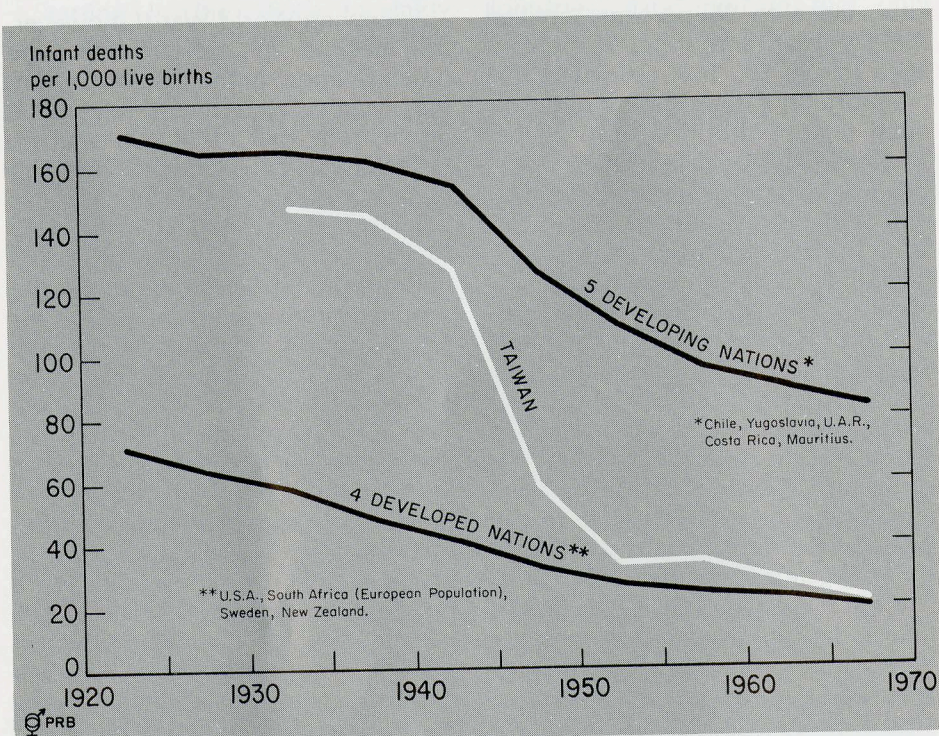
Following World War II, however, the decline in mortality became much steeper. In the case of Ceylon, for instance, the death rate came down from 19.8 to 14.0 in a single year and, in consequence, the estimated expectation of life at birth went up from 43 years in 1946 to 52 years in 1947. In general, in the underdeveloped areas the death rate dropped from an estimated 28 per 1,000 population in the decade 1940-1950 to 17 per 1,000 in the decade of 1960-1970.

In many cases, including Ceylon, this reduction in deaths resulted in large degree from success in the battle against malaria, which was probably the world's most potent single cause of sickness and death before World War II. The widespread use of DDT, sprayed from airplanes, brought the disease under control in many areas. While malaria control may have been the major single factor in declining mortality, other public health measures also played their part. Campaigns to control smallpox on a worldwide scale were undertaken, for instance.

The reduction in infant mortality has particular significance in terms of population pressure, since the survival of children means that they will probably become reproducers themselves. Although deaths among infants remain high in underdeveloped areas, compared with industrialized nations, the decline has been dramatic. Among five less developed countries the mean infant mortality rate went from 165 per 1,000 live births in 1932 to 83 in 1968. The effect was particularly strong in Taiwan, where infant mortality declined to a level close to

Figure 9:

INFANT DEATH RATES, SELECTED COUNTRIES



Source: United Nations. *United Nations Demographic Yearbook*. New York: United Nations, Issues for 1949-1970.

Infant mortality has dropped in developing nations, especially Taiwan.

that of the industrialized nations.

Fertility trends and the demographic transition

Most of the industrialized nations have made a gradual shift and accommodation from age-old high birth rates and high death rates to much lower birth rates and very much lower death rates. Demographers refer to this shift as "the demographic transition." Its distinguishing feature in the West was the approximate parallelism of the gradual declines in the birth and death rates so that net population gain was comparatively moderate

and could be accommodated—at least up to the present—within expanding industrial economies. This contrasts with the very sharp drop in death rates in developing nations without a parallel decline in birth rates, causing rapid population growth.

Figures 10 and 11 show graphically the parallelism of these declines in Sweden, an industrial nation, and the lack of parallelism in Ceylon, a developing nation. European growth rates generally did not exceed 1 percent per year, whereas the developing world now has typical growth rates of 2.5 percent per year.

Basically, the concept of the transition is that with decreasing mortality and a rise in population a subsequent decline in the fertility rate occurred, particularly among the urban, middle-upper class, better educated sectors of the population.

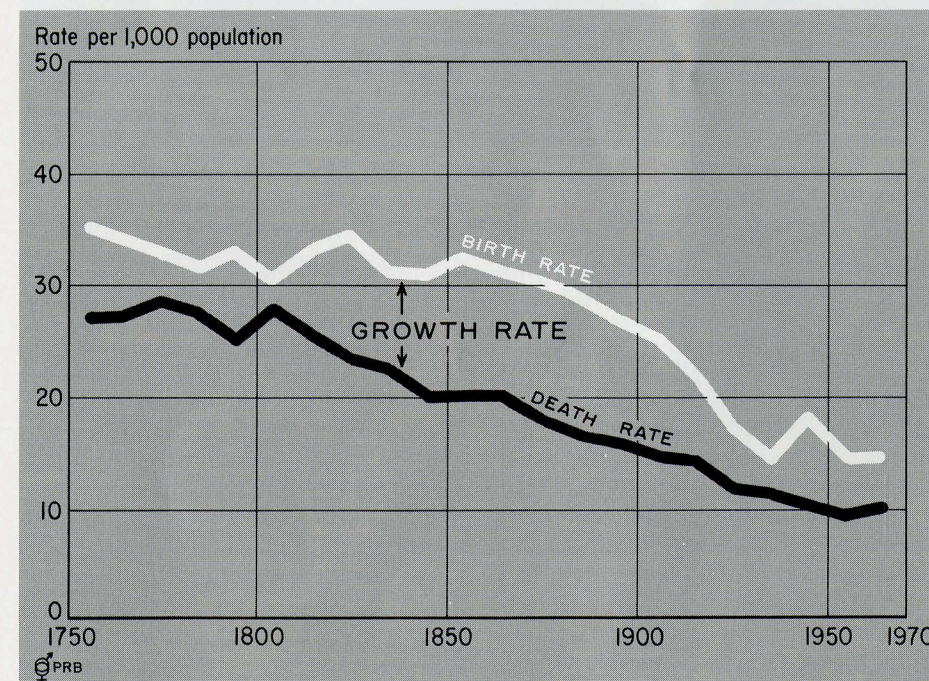
In England, for example, the prosperity of the country—the richest in the world at mid-nineteenth century—and the dynamism of the economy made aspiration to join the middle class a possibility, but an expensive one; limiting the number of children was one way of achieving upward mobility. These social factors, according to some demogra-

phers, probably stimulated a decline in fertility even before the effects of falling mortality began to be felt. And as infant mortality began to decline, the greater survival rate of children, combined with these social factors, probably tended to reduce fertility rates.

The social mobility factor was probably significant, to a greater or lesser degree, in many industrializing nations. As the idea of the smaller family took hold among the middle classes, a movement to spread the word among all classes gave rise to what has been termed the democratization of birth control. The activi-

Figure 10:

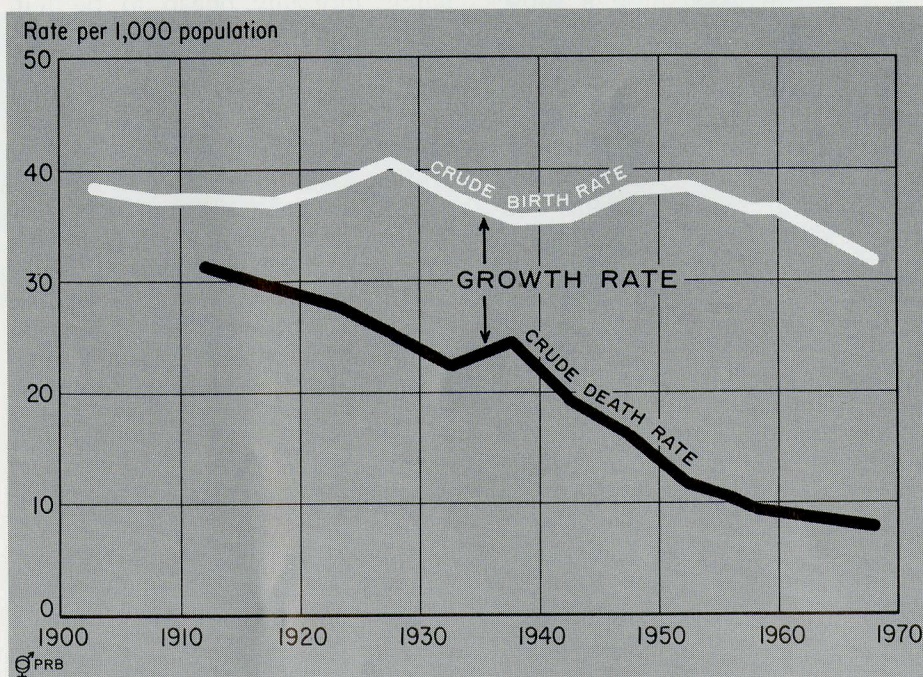
A DEMOGRAPHIC TRANSITION: SWEDEN, 1750-1968



Source: National Central Bureau of Statistics. *Historical Statistics of Sweden. Part 1. Population*. Second Edition, 1720-1967, Stockholm: K. L. Beckmans Tryckerier AB, 1969.

In Sweden, as in much of Europe, declines in birth rates roughly paralleled falling mortality, resulting in moderate population gains.

Figure 11:

EXPLOSIVE GROWTH RATE: CEYLON, 20TH CENTURY

Sources: United Nations. *Population Bulletin of the United Nations*, No. 6 ST/SOA/Series N/6. New York: United Nations, 1962.

United Nations. *Population Bulletin of the United Nations*, No. 7 ST/SOA/Series N/7. New York: United Nations, 1962.

Abrupt drop in mortality in underdeveloped countries such as Ceylon has resulted in a much greater growth than in the developed world.

ties of Annie Besant and Charles Bradlaugh in England and, a generation later, Margaret Sanger in the United States, brought the advocacy of birth control into the open, where it has remained despite continued controversy. The effectiveness of the campaigns are difficult to judge, but it is clear that the small-family system was disseminated throughout much of the social structure in England and other industrialized countries.

The pattern was more pronounced in the cities, which attracted upwardly mobile people for whom fewer children were advantageous.

The effect was reinforced by the fact that children tended to be more of an economic liability than an asset, as they were on the farm, and probably by housing shortages in cities.

In general, birth rates in the more developed regions are estimated to have dropped from 34 per 1,000 population in 1900 to 19 in 1970, a much faster decline than is believed to have occurred in the preceding half-century.

Whatever the cause or causes of fertility decline in industrialized countries, they have not yet been operative in the underdeveloped re-

gions of the world. The sharp drop in mortality in those regions has not been accompanied by a significant decline in birth rates; family planning programs, where they have been tried, have not been particularly effective; even urbanization, as it has taken place in underdeveloped countries, has generally not been accompanied by lower fertility. The result has been a population growth of crisis proportions.

Thus, the social, cultural and economic factors that contributed to fertility decline in industrialized nations are not operating in the same way in the underdeveloped areas of the world. In Europe, mortality decline reflected profound changes in society, which also affected fertility. In developing areas, however, the mortality decline has been a result of medical and other technology which could be imported and applied almost overnight. The cultural changes which were required to affect fertility in the industrialized countries required decades to bring it about, and similar cultural changes have been slow in coming in developing countries.

One of the best indications of the difference in cultural patterns is the number of children desired, as illustrated in Figure 12 (p. 20). In countries with low birth rates the number of children desired is generally considerably lower than in the underdeveloped countries.

The increased population pressures in underdeveloped countries have led to some tentative moves toward changing cultural patterns and introducing some means of reducing the fertility that is so far out of line in relation to mortality. But these efforts have been largely ineffectual so far in influencing fertility.

Governments are discovering that it is much easier to bring in impersonal programs, such as mosquito eradication or even mass vaccinations, than it is to change behavior patterns that are under the control of each individual citizen.* The result has been, and no doubt will continue to be for some years, an exploding population among those nations that can least afford it.

The momentum of population growth

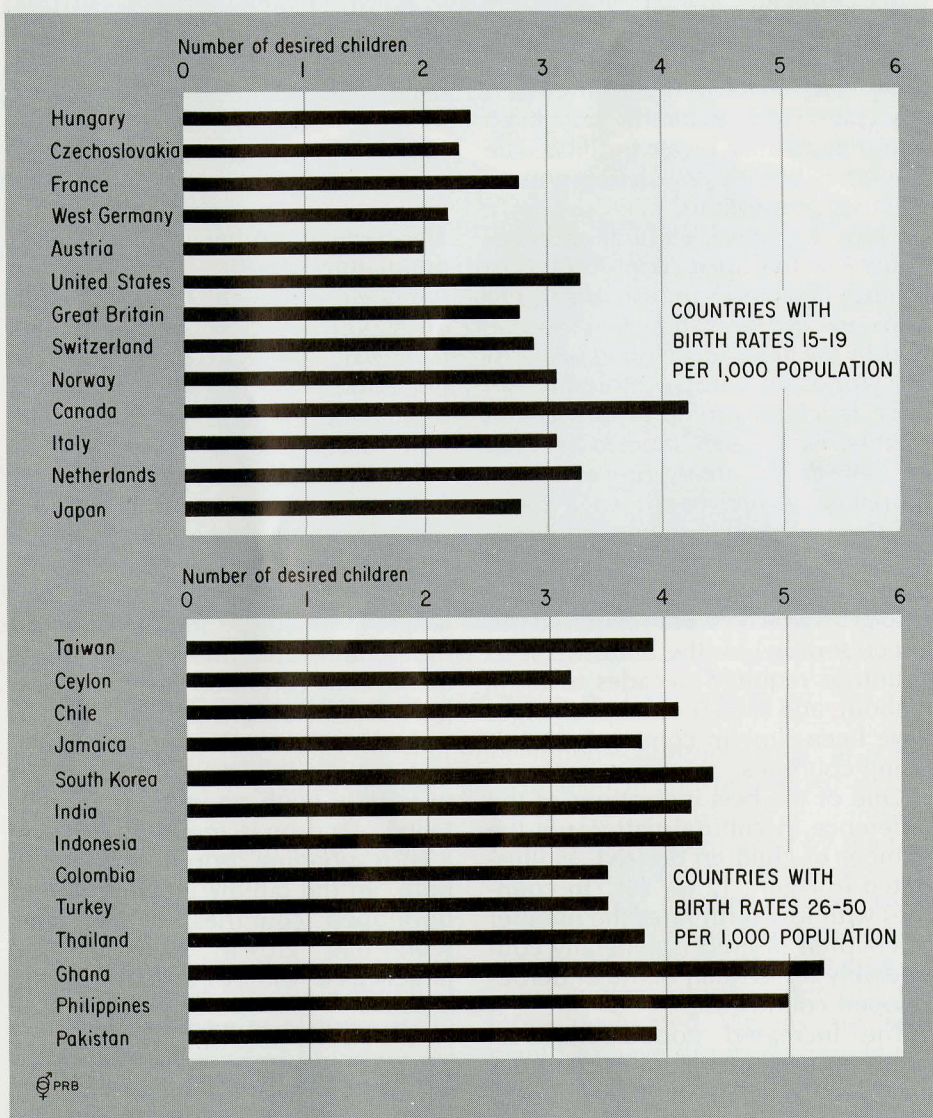
Population growth has a peculiar characteristic: It is enormously affected by the age structure of the population. A very rapid growth in population for a decade or a generation causes a significant change in the age structure, which will be felt for a long time thereafter—perhaps for centuries. It is extremely difficult to slow down population increase after a surge of rapid growth. The longer the surge the greater the momentum and the harder it is to achieve a condition of very slow growth or non-growth.

An increase in the rate of population growth results from an increase in fertility (with no increase in mortality) or a drop in mortality (without a corresponding drop in fertility), or both. In the rapidly growing underdeveloped countries, it has been seen that growth has increased largely as a result of a sharp drop in

* Some observers assert that attitudes toward family size were drastically changed by Western colonialism and later technical aid programs imported from the West. Dr. Georg Borgstrom of Michigan State University says that a number of civilizations, including India and Indonesia, "had a clear picture of the limitations of their villages or communities" before foreign intervention disrupted the traditional patterns. Technical aid programs, he says, "made them believe that the adoption of certain technical advances were going to free them of this bondage and of dependence on such restrictions." Such a breakdown in traditional restrictions would accentuate the effects on population growth of the medical-public health technology, since it would lessen cultural pressures to restrict fertility in response to the increased survival of children.

Figure 12:

DESIRED FAMILY SIZE, SELECTED COUNTRIES



Sources: Population Reference Bureau, Inc. 1970 World Population Data Sheet, April 1970.
 W. Parker Mauldin. *Studies in Family Planning*. "Fertility Studies: Knowledge, Attitude, and Practice."
 #7. New York: The Population Council, June 1965.

The number of children desired by people in countries with low birth rates is generally lower than in countries with higher birth rates.

mortality, including infant mortality. As far as it has been measured, fertility, the rate at which women in the reproductive ages are having babies, has not increased in these countries, and in some instances it appears to have decreased somewhat. In any case, increased population growth rates mean that there are a great many young children in proportion to the total population. The children who used to die from all kinds of communicable diseases live and grow up and have families. In rapidly growing countries, the percentage of the total population under 15 years of age is 40-45 percent, with a larger and larger crop of babies each year. The number of youngsters who mature and become parents increases and a second boom effect is created.

The age pyramid of India, Figure 13, shows clearly why it is almost inconceivable that India's population can stop growing within the twentieth century except as a result of unimaginable disaster.* Each year the number of young people who will mature and become parents is much larger than the number of parents who will move out of their reproductive years, and very much larger than the number of people who will die. Even if Indian parents should decide by 1985 to bring their fertility down to the replacement level and have mostly two-child families with a minority of larger families, the result would be that India would grow to a population of well over a billion by the middle of the twenty-first century. If the present fertility and mortality patterns were to continue to the year 2000, the population

* See "India: Ready or Not, Here They Come," *Population Bulletin*, November, 1970.

would reach 1.5 billion in that year.

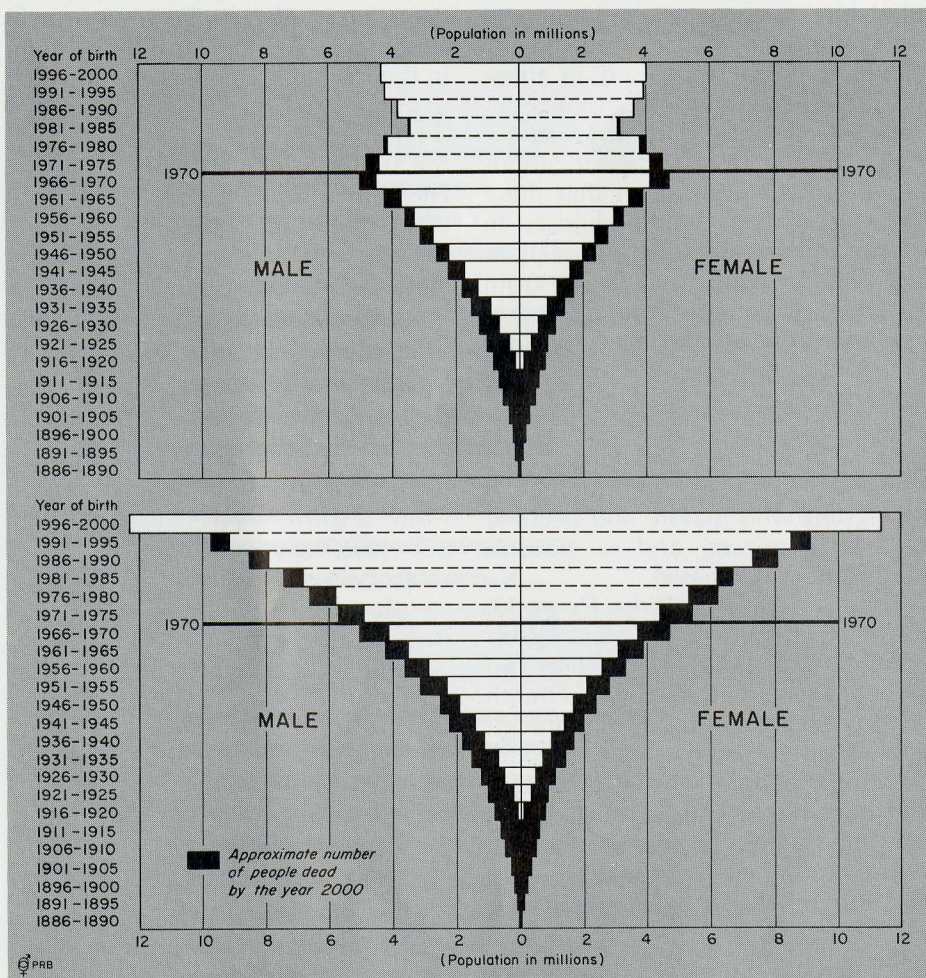
This momentum of population growth can also be seen in respect to the post-World War II baby boom in the United States—a case in which a sharp increase in fertility (rather than a sharp drop in mortality, as in the underdeveloped world) was the cause of a rapid population growth rate. It is best illustrated by using the hypothesis that the people of the United States might conclude that the goal of achieving a stationary population would be desirable and decide to achieve it as soon as possible—say next year. Assuming, for this illustration, no immigration, this would mean that the birth rate would have to be brought down from its current level of about 18.2 per 1,000 per year to equal the death rate of about 9.3 per 1,000 per year. In other words, the birth rate would have to be cut nearly in half.

It might be assumed that population growth would stop if parents had no more than enough children to replace themselves. But here the momentum of past fertility patterns comes into play. Because of the great bulge of the population now coming into the reproductive age—those who were born during the postwar baby boom—halting population growth next year would require that families limit reproduction to an average of 1.2 children each for the next 20 years or so, according to demographer Tomas Frejka. Such a drastic reduction in fertility is extremely unlikely.

But even stranger behavior would be required of American families over a longer period if the nation were determined to stabilize its population at the current level. After the sharply reduced fertility of the next 20 years the age structure

Figure 13:

INDIA: AGE DISTRIBUTION PROJECTIONS, YEAR 2000



Source: U.S. Bureau of the Census. Statistics based on projections received from the International Demographic Statistics Center, 1970. (Unpublished.)

Projected age distribution in the year 2000 if fertility declined to replacement by 1985 (top) and if present birth and death rates continue.

would be such that population would begin to decline. In order to maintain a steady population, fertility would have to rise again, reaching a peak of 2.8 children per family by 2035. In the following 30 years fertility would have to drop back down so that the number of children

per family would sink to 1.4 in 2065. Thereafter, fertility would have to oscillate for close to four centuries, as shown in Figure 15 (p. 24).

The alternative to such oscillations for a nation that seeks to achieve a stationary population would be to bring its fertility rate down to the

replacement level gradually and hold it there. The momentum of past growth would then take another 65-70 years to work itself out. This, too, has been graphically portrayed by Dr. Frejka.

Dr. Frejka calculated the ultimate size of the U.S. female population on 11 different assumptions about the rapidity with which the fertility of women would drop to the replacement level. His lowest assumption was an immediate drop to that level. His second assumption was that it would take 5 years for this drop to occur; the third assumption is based on a 10-year decline, and so on up to 50 years. The results of his pro-

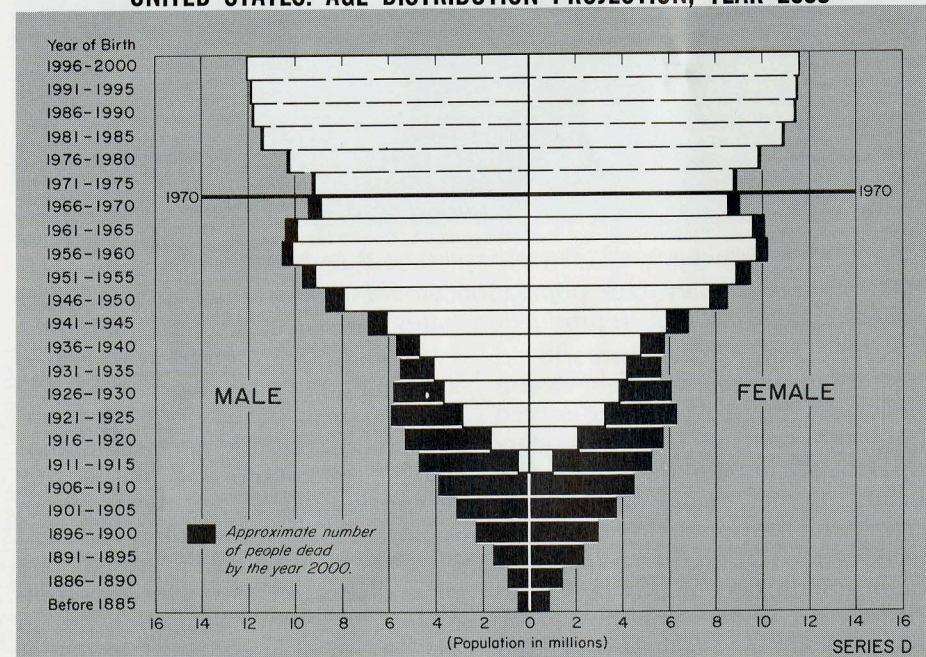
jections are shown graphically in Figure 16 (p. 25).

This graph shows clearly what is meant by the momentum of population growth. It takes two-thirds of a century, after the fertility rate falls to the point where women are having just enough female children to replace themselves, before a stationary population can be achieved.

The analysis of what it would take to achieve a stationary population in the United States is of interest for two reasons. It illustrates the effect of age structure momentum over a long period of time, and it demonstrates that a quick achievement of zero population growth would re-

Figure 14:

UNITED STATES: AGE DISTRIBUTION PROJECTION, YEAR 2000

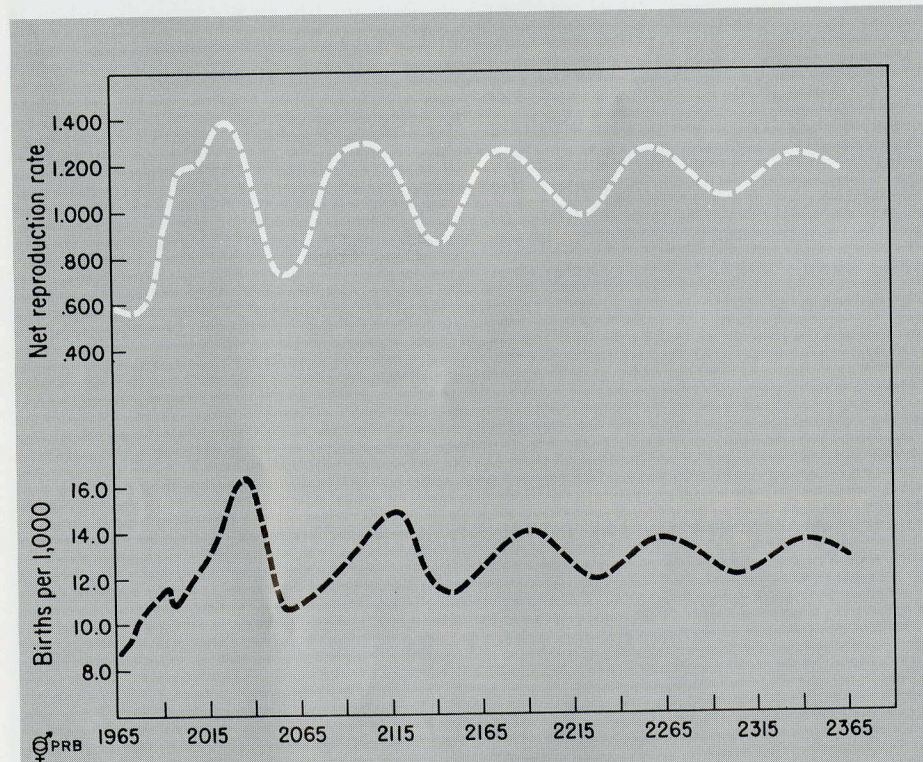


Source: U.S. Bureau of the Census. "Projections of the Population of the United States, by Age and Sex (Interim Revisions): 1970 to 2020," *Current Population Reports*, Series P-25, No. 448. Washington, D.C.: U.S. Government Printing Office, 1970.

The bulge of the baby-boom years, 1946-1960, will be reflected in the number born in the last two decades of the twentieth century.

Figure 15:

CHANGES REQUIRED TO MAINTAIN A PROJECTED CONSTANT TOTAL POPULATION



Source: Frejka, Tomas. "Reflections on the Demographic Conditions Needed to Establish a United States Stationary Population Growth," *Population Studies*, Vol. 22, No. 3, November 1968.

Achieving a stationary U.S. population would require oscillating changes in birth rates and net reproduction rates for close to four centuries.

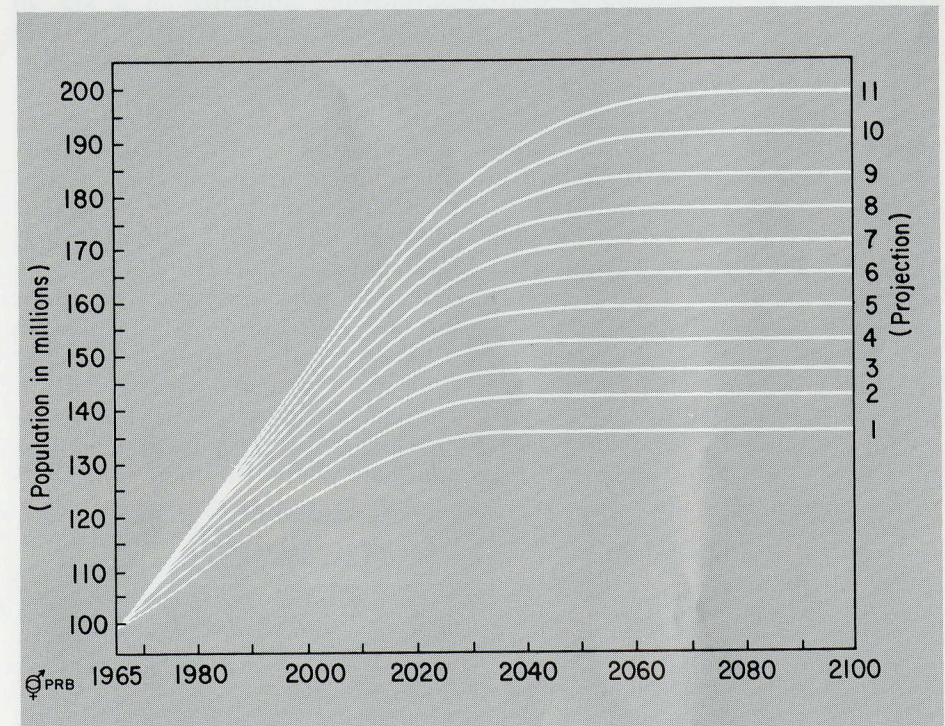
quire some unusual social behavior. Of course, there is nothing sacred about the concept of a stationary population. Population could also decline. In fact, many who are concerned with the population explosion are now advocating that zero population growth become, as rapidly as possible, an upper limit not to be exceeded, rather than a lower limit to be reached eventually.

The worldwide population predicament has two dimensions. In the underdeveloped world, with population growth in the range of

2-3 percent, the situation has clearly reached crisis proportions. In countries that have undergone the demographic transition, and particularly in the United States, the problem seems at first to be of a different order of magnitude—a growth rate of one percent or so seems somehow less urgent. Yet when put in the context of other world problems, including economic development and the preservation of the ecosystem, the growth of the industrialized countries appears fully as critical as that in the rest of the world. Some

Figure 16:

GROWTH OF U.S. FEMALE POPULATION, 11 PROJECTIONS, 1963-2100



Source: Frejka, Tomas. "Reflections on the Demographic Conditions Needed to Establish a United States Stationary Population Growth," *Population Studies*, Vol. 22, No. 3, November 1968.

Depending on when replacement level was reached, U.S. female population would reach from 135 to 200 million before levelling off.

of the relationships between population growth and other problems will be discussed in the next section of this *Bulletin*.

POPULATION, ECONOMIC DEVELOPMENT AND THE WORLD ECOSYSTEM

The population explosion is of mammoth dimensions, but it is not the only mammoth problem. It must be set in the context of efforts to bring a decent level of living to the world's poor, and to avoid exhausting the world's resources and polluting the earth's ecosystem in the process.

Besides exporting the medical and

public health revolution to the rest of the world, the Western industrialized nations have also tried, since World War II, to spread the technology of industrialization and economic development. In general, the effort has not been very successful. Although the economies of the poorer nations, as measured by per

capita income, have advanced, they have not been going up nearly as fast as those of the developed countries. The income gap has been widening, not narrowing.

Contributing to the widening of the gap is the fact that population is growing fast in the poor, non-industrialized countries and not as fast in the industrialized countries. The rich are getting richer and the poor are getting, not only poorer, but more numerous. Figures 17 and 18 dramatically show this growing income gap.

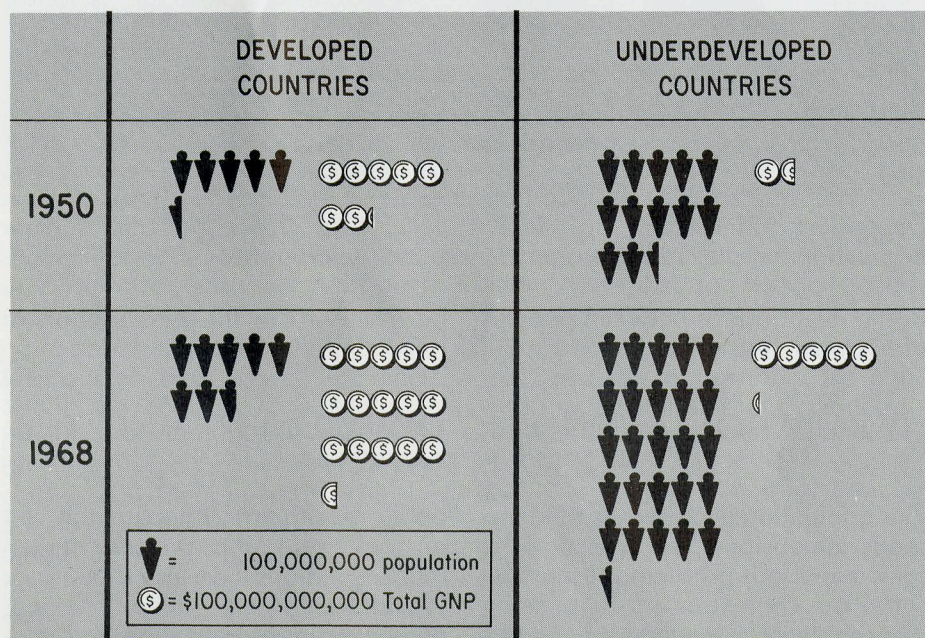
In this way the population explosion is accentuating and aggravating one of the most explosive questions in the world's near future:

How long can the industrialized nations continue to exist as islands of growing affluence in a sea of rising poverty? It is also making more critical the question that only recently has been asked seriously: How long can the world's ecosystem continue to support and feed growing numbers of consumers of irreplaceable natural resources and polluters of the world's water, air and natural environment?

If the non-industrialized nations are to avoid future catastrophe on a massive scale, they have no other option but to devote their efforts on an unprecedented scale to (1) increasing their capacity to feed and adequately nourish their own citi-

Figure 17:

INCOME AND POPULATION GROWTH COMPARED

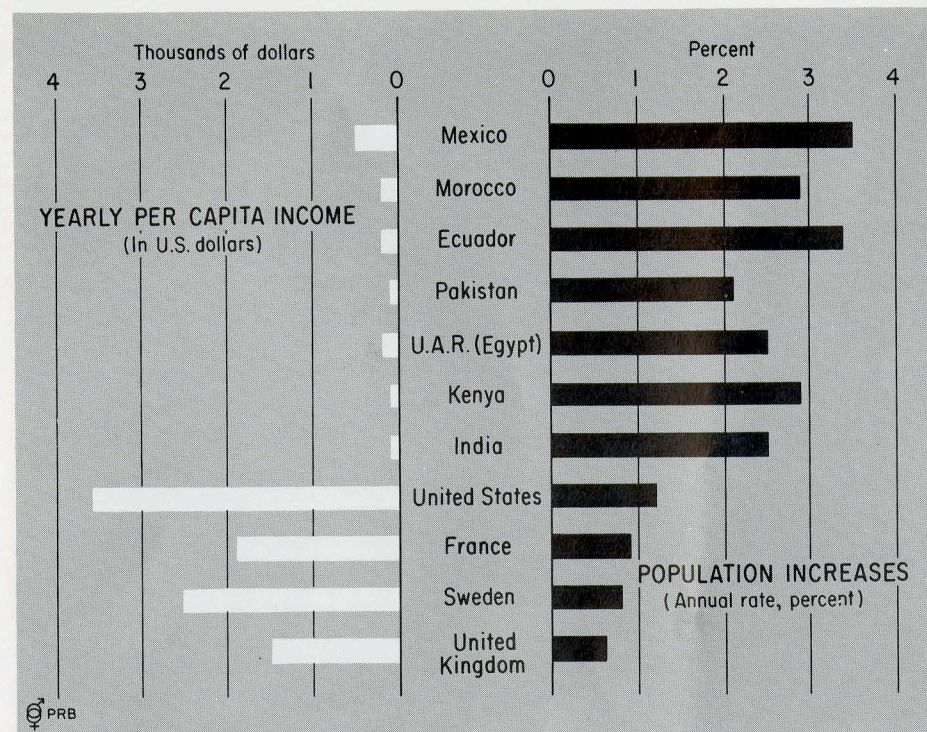


Source: United Nations. *Yearbook of National Account Statistics, Vol. II: International Tables, 1969*. New York: United Nations, 1970.

As population in developing countries has boomed, income has not risen as much as in industrialized countries; the income gap has grown.

Figure 18:

PER CAPITA INCOME AND POPULATION GROWTH, SELECTED COUNTRIES



Sources: United Nations. *United Nations Statistical Yearbook*. New York: United Nations, 1970.
 United Nations. *United Nations Demographic Yearbook*. New York: United Nations, 1970.
 Population Reference Bureau, Inc. *1970 World Population Data Sheet*. April 1970.

Countries with low per capita income have high population growth.

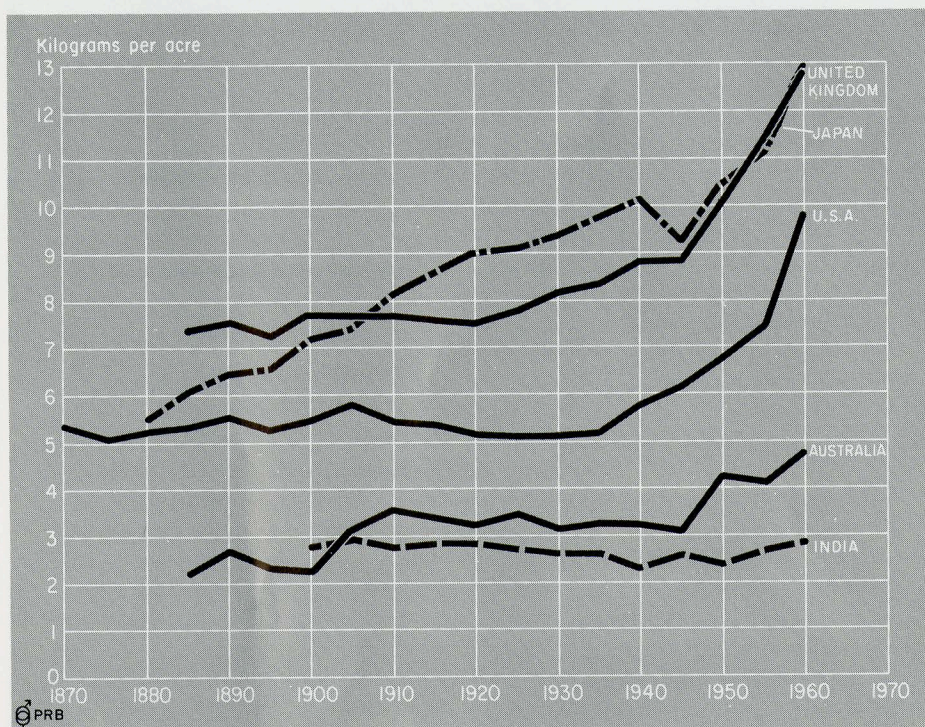
zens, (2) bringing the birth rate down sharply, and (3) increasing their non-agricultural output through savings, investment and creative ingenuity. The creative ingenuity may be the most important component of all. Help from the industrialized world may buy additional time and defer or ameliorate crises, but such voluntary aid cannot offer adequate or permanent solutions.

Improving the quantity and quality of food per person for the underdeveloped world is an uphill struggle, in major degree because of

the fast rates of population growth. With population growing at a rate of 2.5 percent per year in the typical agrarian nation; with quantitative intake at sub-marginal levels so that the bodies and minds of young children are not having adequate opportunity for healthy development, adequate nutrition is of highest priority. Some progress is being made. Yields per acre of grain crops have increased rapidly in the last century, as shown in Figure 19 (p. 28). Even more encouraging has been the dramatic improvement in the yield of new

Figure 19:

GRAIN YIELD PER ACRE, SELECTED COUNTRIES, 1870-1960



Source: Brown, Lester R. *Increasing World Food Output: Problems and Prospects*. Foreign Agricultural Economic Report No. 25. Washington, D.C.: Government Printing Office, 1965.

Grain yields have increased in this century in some countries; new strains of wheat and rice promise similar gains for agrarian nations.

strains of wheat and rice that are particularly well suited to the climate of countries like Mexico, Pakistan and India. Dr. Norman Borlaug received the Nobel prize for peace in 1970 for his work in developing those new strains.

But Figure 20 (p. 29), shows the worldwide situation and the tremendous distance yet to go. The upward trend in agricultural production may, for a time, keep up with the 2.5 percent rate of population growth, but it cannot keep this growth rate up for a very long period.

Population growth not only creates pressure on agriculture; it also increases the difficulty in finding jobs for the growing numbers in largely non-industrialized countries. Dr. William Thiesenhusen of the University of Wisconsin points out (*Science*, March 5, 1971, p. 868) that, "In Latin America, regardless of what happens to the birth rate in the future, the labor force will keep growing rapidly for a generation. In countries where unemployment is already a serious problem, such a prospect is chilling."

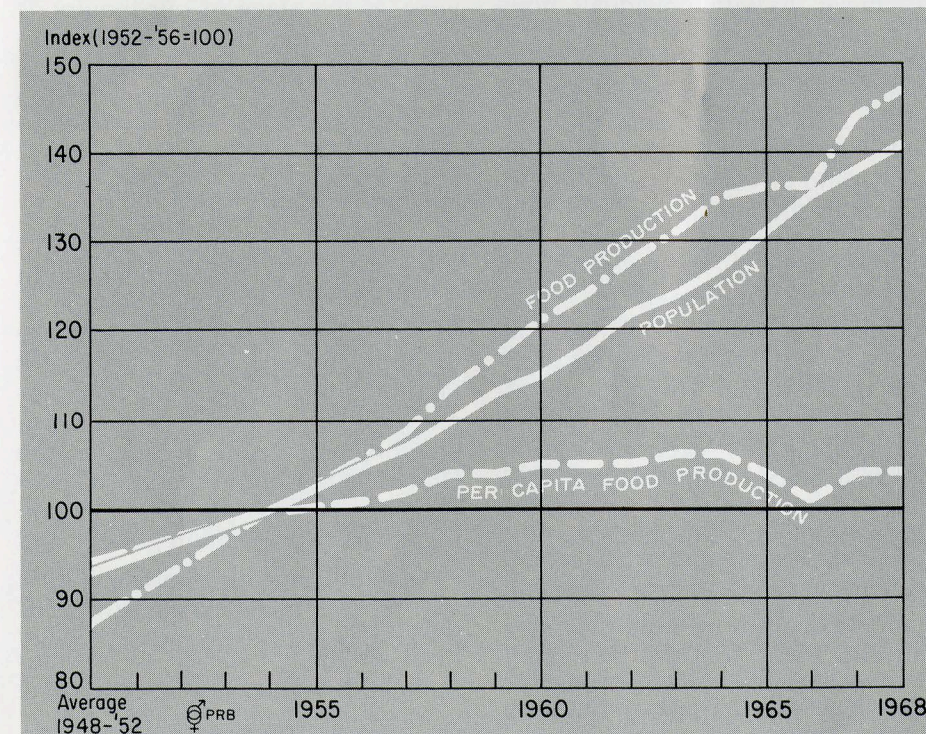
There are differences of opinion and of theory as to whether and how the poor nations can raise their incomes and lower their population growth rates sufficiently to bring their living standards up to levels comparable to the industrialized nations. On the one hand, there is great apprehension that population growth in the non-industrialized nations may be out of hand; the possibility may be remote that the developing world may achieve a demographic transition to low birth rates to match their low death rates in time to avert catastrophic famines.

In contrast, some people retain the hope and even the conviction that such a demographic transition may come about much more rapidly than present indications give us ground for believing. Without a rapid reduction in birth rates to or below replacement levels, most of the developing nations have little prospect of accelerating their painfully slow increase in per capita income.

Regardless of theory, however, reducing the birth rate in agrarian nations has so far proven, in practice, even more difficult than increasing the food supply. While many devel-

Figure 20:

WORLD POPULATION AND FOOD PRODUCTION, 1948-1968



Source: Food and Agriculture Organization of the United Nations. *The State of Food and Agriculture*, 1969. Rome: Food and Agriculture Organization, 1969.

World food production has barely kept pace with population growth.

oping nations have instituted official family planning programs, most have not been in operation long enough to show much effect, and results from those that have are not encouraging. The extent and effects of various family planning programs will be discussed in the next section of this *Bulletin*.

Increasing non-agricultural output of the agrarian nations through savings, investment and ingenuity is likewise very slow in coming. Economists generally agree that it requires about \$3 per capita of investment annually to increase annual output by \$1 per capita in underdeveloped countries. This amount of saving and investment is hard for poor nations to achieve. As with individuals, however, rates of saving within national societies depend on more than income levels. They depend on the actual opportunities and the perceived advantages which come from savings and investment, and the willingness of the individuals or the nations to arrange their lives and their institutions to exchange short-term hardship for long-range advantage.

While the non-industrialized nations are faced with enormous problems of elemental living, the industrialized nations are preoccupied with keeping their economies growing at a steady clip, keeping their more slowly growing populations fully employed, controlling the pollution they are generating at a high rate, fulfilling the demand for more numerous and more expensive services and trying to keep their complex, interrelated societies from falling apart. In the process, they are consuming the earth's scarce fuels and mineral resources at a prodigious rate with every expectation of continuing to increase their rates of

consumption on a per capita basis and especially on an absolute basis. In this regard, resource consumption is analogous to population increase: It cannot continue to double at an accelerated rate.

To what extent population problems have aggravated the social and economic problems of the United States has been a matter of increasing interest and dispute. The issue is now being studied by the Commission on Population Growth and the American Future authorized by Congress in March 1970 and appointed by the President. In its interim report issued in March 1971, the Commission expressed its preliminary conclusion in these words: "Our view, at this stage of our inquiry, is that population growth of the magnitude we have had since World War II has aggravated many of the nation's problems and made their solution more difficult." The Commission's final report in March 1972 will be awaited with great interest.

What is also in dispute, but without comment by the Commission in its interim report, is the question as to the extent to which the increase in population of the United States (and other high consumption economies) may place a stress on the world environment. Some argue that the United States should spend whatever is necessary to control its pollution regardless of population growth, and that U.S. growth in the consumption of the natural resources of underdeveloped nations is actually beneficial to them because it provides them with needed foreign exchange with which to industrialize.

Others point out that population growth in affluent countries puts a disproportionately heavy load on the environment. One American, for ex-

Figure 21:

SUPPORT OF FAMILY PLANNING IN UNDERDEVELOPED AREAS

(population figures given in millions)

	Government Support (population)	Percent	Little or No Government Support (population)	Percent	Total (population)
All Developing Countries	1964	79	514	21	2478
Africa	146	42	198	58	344
Latin America *	76	30	173	70	249
East Asia	789	98	15	2	804
Other Asia	953	88	128	12	1081

*excludes Argentina and Uruguay

Source: Nortman, Dorothy. "Population and Family Planning Programs: A Factbook." *Reports on Population/Family Planning*, December, 1969.

Almost two billion people—79 percent—in developing areas live in countries where there is some government support of family planning.

ample, consumes some 30 times as much oil and scarce minerals as one Pakistani. He is responsible for a very much higher level of pollution of the air and water of the earth. His consumption makes him more responsible for overfishing the seas, exterminating animal species, poisoning and killing inland lakes and other degradations. Some observers assert, therefore, that even a comparatively slow rate of population growth in the United States may have as deleterious a long-range effect on man's total environment as 10 or 20 or 30 times faster growth of an equivalent population in low consumption agrarian economies.*

Family planning programs in non-industrialized countries

In the last decade awareness of the

*Space precludes a detailed analysis of this interesting argument, but those wishing to pursue it further can find it more extensively discussed in the pages of *Science*. Two recent articles are "Man and His Environment" by Ansley J. Coale, *Science*, Oct. 9, 1970, p. 132, and "Impact of Population Growth" by Paul R. Ehrlich and John P. Holdren, *Science*, March 26, 1971, p. 1212.

population crisis in developing countries has increased to the point that three-quarters of the people in those areas live in countries where there is support of family planning activities. (See Figure 21, above.)

Since most of these programs have been in effect for such a short time, it is hard to judge their effectiveness.

Even if the data were available, it would be difficult to judge how effective family planning programs were in affecting fertility rates. It was noted in an earlier section that fertility in Europe began to drop well before the start of family planning campaigns, indicating that there was wide, though largely unspoken and gradual acceptance of the small-family idea. The pattern was similar but more accelerated in Japan and Taiwan, two countries where fertility data are available for much of the present century. Fertility declined in Japan prior to World War II, despite a policy of the nationalist government to promote population growth; when the 1948 Eugenic Protection

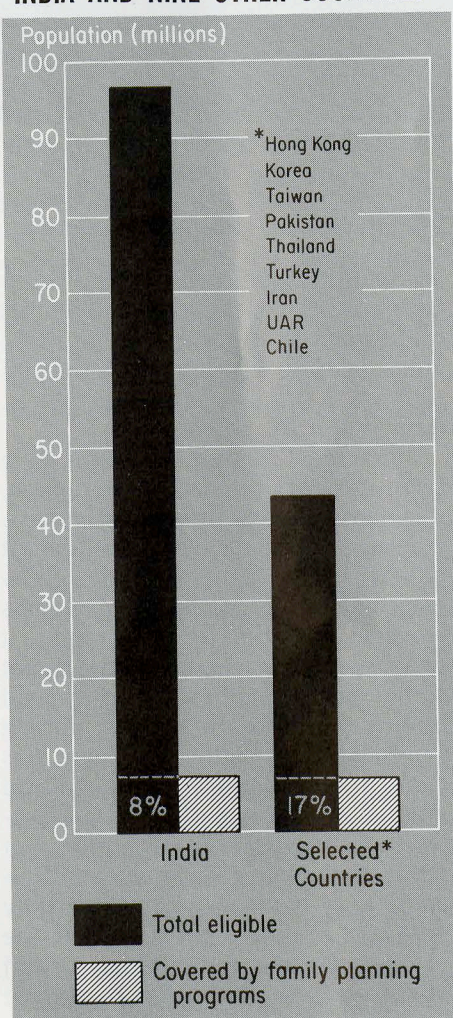
Law made contraceptives, abortion and sterilization available at low cost, there was wide public acceptance of family planning and the birth rate dropped almost by a half in a single decade. In Taiwan, fertility fell significantly for more than a

decade before the government's official family planning program was instituted in 1963.

Thus where family planning has been effective, cultural acceptance of the idea seems already to have been present. On the other hand, proponents of family planning programs argue that the very presence of an official program can be an engine of cultural change leading to wider acceptance of reducing fertility—if the program is conducted in a way that does not do violence to deeply held cultural norms and thus alienate more people than it converts.

One obvious problem is the difficulty in reaching enormous numbers of people, particularly when they are clustered in hundreds of thousands of villages. India, for example, has had an official program of family planning since 1952, and since 1965 has strongly pushed the message of birth control. Yet only 8 percent of the eligible female population has been reached by the program. The result is that some 89 million women in the reproductive age group in India are not even covered by a family planning program. (See Figure 22.) Even where the percentage of coverage is greater, as in the nine countries grouped together in one bar in Figure 22, substantial numbers of women remain beyond the reach of the government-sponsored family planning centers.

Figure 22:
**SCOPE OF FAMILY PLANNING,
INDIA AND NINE OTHER COUNTRIES**



Many women of reproductive age are unreached by programs.

THREE MODELS OF THE FUTURE

Man is slowly becoming aware of his population predicament. He is gradually realizing that he is in a most extraordinary and abnormal period of human development—a period of such rapid growth that it cannot long be sustained. What, then, is the probable outcome of present trends?

Essentially, there are three principal ways by which man may come into more stable balance with his environment. The first would be the most tragic for man and many other species of animal life. It might be called the "Population Crash Curve." Population would continue to double at the current rate of about three times a century until we overshoot the carrying capacity of the earth. Many delayed adverse effects upon the environment would cumulate and culminate in a precipitous decline through extreme famine, excessive pollution, social chaos, high death rates from communicable and chronic diseases, wars to hold or seize the ever-scarcer resources of the earth, very low birth rates and other factors. In the process of severely overtaxing his environment, man would also undoubtedly continue the process—a process which is much further along than many now realize—of denuding the earth of numerous other species of animals. These animals have contributed to an ecological balance which has sustained man through hundreds of millennia. Without them, we do not know what kind of an ecological balance would be possible for a very much smaller number of men in future centuries.

A schematic diagram of man's

"Possibility No. 1" is shown in Figure 23. This kind of a population curve is similar to that of various animal species or groups when some factor disturbs environmental relationships and causes the animal populations to expand at a rapid rate and overshoot the capacity of the environment to sustain the greatly enlarged numbers. Hares, deer, elephants and other mammals studied by ecologists have been found to follow this kind of a curve when predators are removed or, more rarely, when food supplies suddenly increase.

Geochemist Harrison Brown, in his book *The Challenge of Man's Future* published in 1954, foresaw the possibility of a population collapse for mankind and a return to an agrarian economy. He foresaw a spiralling effort to increase living standards while population doubled two to three times a century, thus drawing ever more heavily upon the earth's fossil fuels and mineral resources. He foresaw the rapid and continuous increase in the production and use of power, a major part of which would be needed to convert lower and lower grade ores to usable levels of refinement. Eventually, all this must reach an upper limit, he emphasized. And when the population curve exceeds the earth's continuing carrying capacity, it (and most other curves) might plummet sharply.

Recently, a similar analysis has been developed by a group of scientists at the Massachusetts Institute of Technology working on a continuing "Project on the Predicament of Mankind." They have constructed computer models of the future using a

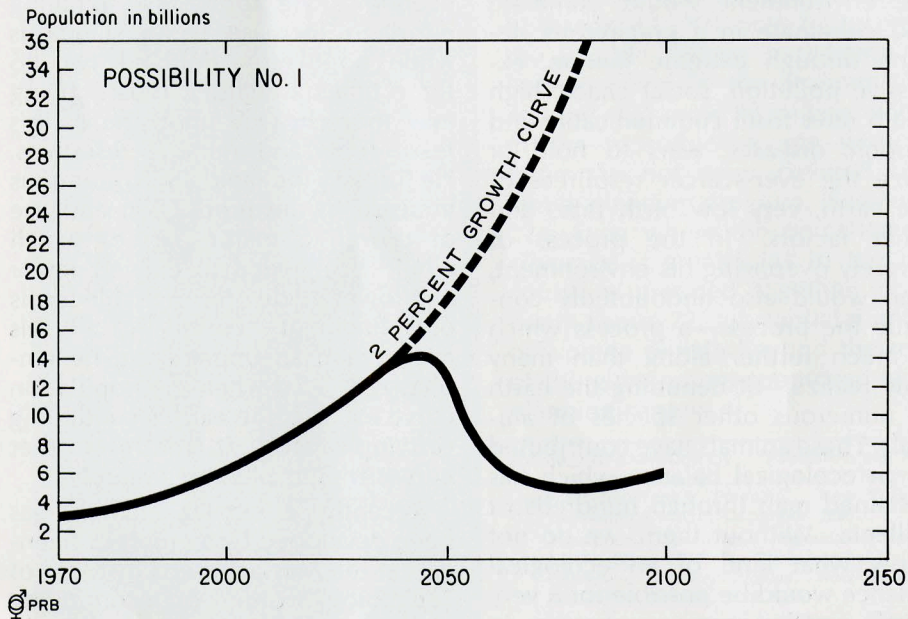
Sources: Nortman, Dorothy. "Population and Family Planning Programs: A Factbook," *Reports on Population/Family Planning*. New York: The Population Council, December 1969.
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variety of assumptions. According to Dr. Dennis Meadows of MIT's Alfred P. Sloan School of Management, their preliminary models show that if current trends are not reversed there could be a decline in population of 50-80 percent during the twenty-first century.

Today no one can predict with any assurance how likely Possibility No. 1 may be, or at what point the curve might turn sharply downward. A little simple arithmetic, however, coupled with the judgments of specialists in the field of resources, will show that the possibility would be high of its happening in the twenty-first century *if population were to continue to double at its current rate of approximately three times a century.* World population in the year 2000 would be not less than 6 bil-

Figure 23:

POSSIBILITY NO. 1. THE "POPULATION CRASH CURVE"



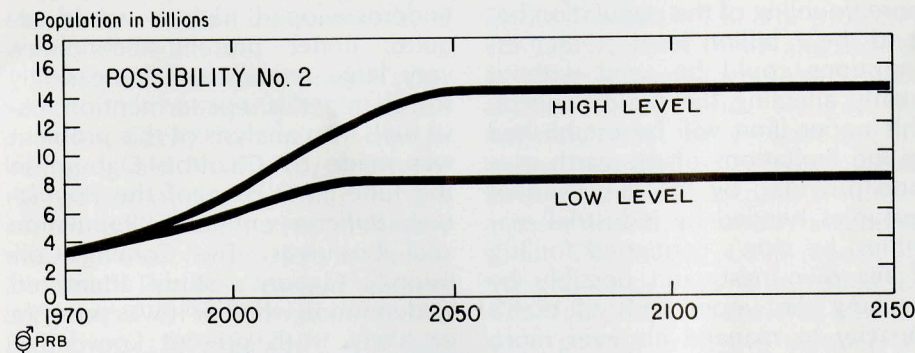
Continued population growth at the current 2 percent rate could lead to a calamitous population crash sometime in the twenty-first century.

lion; in 2033 it would be 12 billion; in 2066 it would be 24 billion; and in 2100 it would be 48 billion. It is the judgment of resource experts that the earth simply could not sustain any such number as 48 billion human beings at what we think of as a humane standard of living, and probably not at all.

If there is a significant chance that the precipitous decline—a new dark age of unprecedented bleakness—may come about if the human population continues to double at near its current rate, a substantial part of man's intelligence should be directed to assessing more precisely the imminence of that possibility and trying to avert it. "Letting nature take its course" cannot be depended upon to avert the prospect that the twenty-first century may become the

Figure 24:

POSSIBILITY NO. 2. "GRADUAL APPROACH TO ZERO POPULATION GROWTH"



Support of a world population at a level of 14 or even 7 billion presents serious problems for agriculture, resources and environment.

darkest century of man.

Possibility No. 2 is diagrammed schematically in Figure 24. It might be called the "Gradual Transition to Zero Population Growth." It is based on several assumptions: (1) that we have not already passed the population level at which the earth can continuously sustain mankind at a reasonable level of health and culture, (2) that man can and will slow down his rate of growth and level off the population within a limit which is continuously sustainable by the earth's ecosystem, and (3) that when world population does level off, there will be enough resources and political and management capability to achieve what has been called a "steady state" in which births match but do not exceed deaths.

The lower and upper lines of Possibility No. 2 illustrate well the nature of the world's population predicament. The lower line is based on the assumption that worldwide fertility rates will drop to the replacement level by 1985, which means that parents will be having just enough children, on the average, to replace themselves. It means that

over most of the globe where high birth rates prevail, these birth rates would have to be cut in half or even more in a mere 15 years. And so great are the numbers of young people approaching their reproductive years (40-45 percent under age 15 in most of the underdeveloped world) that even when fertility comes down to the replacement level, there will be a second enormous population surge when the children of the first baby boom replace themselves.

The momentum of population growth is so great that even under this extremely optimistic assumption, the steady state could not be achieved with less than about 7 billion people. This, therefore, appears to be the lowest level at which population might conceivably level off without markedly increased death rates or sub-replacement levels of fertility. The ultimate steady-state population of 7 billion would be reached under this assumption about 70 years after the fertility rate reached the replacement level, or about 2055.

The upper line of Possibility No.

2 is based on an arbitrarily chosen upper limit which would allow one more doubling of the population beyond the 7 billion level. Other assumptions could be used without greatly affecting the basic concept. This upper limit will be established by the limitations of the earth as a food provider, by the depletion of resources needed by industrial machines, by man's continued fouling of his own nest, and possibly by reaching the upper limit of man's capacity to manage his ever more intricate and interrelated economic, political and social systems.

Agricultural analyst Lester Brown is becoming increasingly skeptical that the world can adequately feed even 7 billion people. Brown points to growing agricultural stresses on the earth's ecosystem caused by man's continuing efforts to expand his food supply—such as converting too much forest land to crop land, and more extensive and intensive use of fertilizer—as causing erosion, eutrophication of lakes (like the killing of Lake Erie), extermination of animal species, dust bowls and other adverse effects on the environment. Nobel prizewinner Norman Borlaug says that the new miracle seeds which have generated the green revolution can, at most, buy only two or three decades within which to bring birth rates down sharply. Agricultural resource expert Georg Borgstrom says that fresh water will become a limiting factor much more rapidly than we realize and doubts that we can sustain a world population at the high levels described graphically in Figure 24 (p. 35).

Not only is there the problem of adequate nutrition for the expanding world population; there is the problem of trying to lift half to two-

thirds of the world out of deep poverty. The industrialization of the underdeveloped nations would require, under present technology, very large amounts of increasingly scarce minerals, not to mention fossil fuels. An analysis of this problem was made by Charlton Ogburn in the June 1970 issue of the *Population Bulletin* entitled, "Population and Resources: The Coming Collision." Ogburn's study attempted to determine whether it was possible or likely, with present knowledge and technology, that a world population of a "mere" 5 billion could find the resources to bring the average standard of living of the entire world up to 1970 U.S. standards. Industrialized nations would continue to raise their standards but the non-industrialized nations would make up for some lost time and industrialize faster. Under his assumptions there would be some reduction in the gulf between the rich and the poor nations.

But Ogburn's analysis concluded that known resources and foreseeable technology would not support 5 billion people at 1970 U.S. standards. It would require a worldwide level of consumption 10 times as great as the 1970 world level. In his words, "We must lower our sights even lower than this conservative projection (of population) if we are to preserve a livable environment." If we cannot support 5 billion people at modern levels of living, it is clear that the 7 billion which the world will have under the most speedy transition to a zero population growth rate can only be accommodated under what seem to us difficult and perhaps unacceptable conditions. The rich would continue to be very rich and the

poor very envious. And if this condition were to exist at 7 billion, it obviously would be exacerbated greatly at 14 billion.

The most important single factor which might materially increase the earth's capacity to support human beings would be the harnessing of the power of the H-bomb for the generation of electricity. Whether this will ever be possible is not at all clear. The best current guesses are that if it should prove to be technologically feasible, it will take at least two decades to develop fusion power and another decade to bring it into significant production. It would not, therefore, have any impact on power production during the twentieth century. Meanwhile, the population clock keeps ticking on. Even with an almost inexhaustible supply of power, which the fusion process might provide, there are upper limits to food production, and these seem very likely to be reached in the twenty-first century.

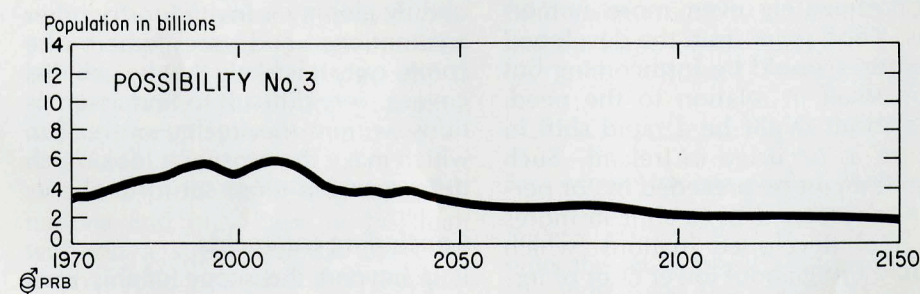
The Population Reference Bureau recently published a speech by Herman Miller, Director of the Population Division of the Bureau of the Census, entitled, "Population, Pollution and Affluence." In it, Dr. Miller

projected to the year 2000 the population growth and the income growth of the United States. He projected existing economic trends and showed an average family income of \$21,000 at the century's end. He gave no indication that he thought the increase in American affluence would level off at this figure; this would be a point on a continuously ascending scale. This brings out in bold relief the picture of a world in which the rich would be getting richer and the poor poorer, with the numbers of the poor continuing to rise.

The third possibility, shown in Figure 25, is labelled the "Modified Irish Curve." Its name is derived from the experience of Ireland in the 1840s, when a disastrous potato famine occurred, and the country's most unusual response to that experience. Ireland's population before the famine reached more than 8 million, of whom 6.5 million lived in what is now the Irish Republic and about 1.5 million in Ulster. In the 10 years during and after the famine, the population dropped by 24 percent. More than a million died from the direct and indirect effects of the famine; 2 million emigrated, mostly to the United States,

Figure 25:

POSSIBILITY NO. 3. THE "MODIFIED IRISH CURVE"



A number of serious disasters could cause temporary declines in population and be followed by a consensus to keep population down.

and the remainder changed their basic way of life. Judging by their actions, they arrived at an unstated social consensus that they would not again overpopulate their island, as they had done prior to the potato famine; they would reduce their dependency on a single crop, potatoes, by developing dairy, beef-cattle and other types of farming; and they would modify their family structure so as to produce fewer and smaller families. Their society shifted to patterns of non-marriage, late marriage and small families, and has continued this pattern until today. In 1940, 80 percent of the Irish men, age 25-29, were unmarried. In 1960, 70 percent of the men 25-34 were unmarried. And the population of the Irish Republic in 1970 was 3 million—less than half its 1840 population. (Ulster's 1970 population was 1.6 million.)

A somewhat similar fate might be in store for the world. Conceivably, the overpopulated agrarian countries might overshoot the carrying capacity of their land and, through a combination of drought, blight and other factors, have famines which would be proportionate to the Irish famine. Emigration very likely would not be a significant outlet, as it was for the Irish. Deaths might be proportionately even more numerous. Food relief from the developed countries would be forthcoming but very small in relation to the need. The result might be a rapid shift in mores as occurred in Ireland. Such a shift might be preceded by, or perhaps succeeded by, a shift in mores in the developed nations which would bring about lower rates of fertility—possibly sub-replacement levels of fertility. Such sub-replacement levels might, thereafter, by consensus

become worldwide.

It is difficult to predict the point at which a hypothetically declining population would level off or whether the curve might turn back up. It might fluctuate for centuries. Some analysts have expressed concern that a long decline would be difficult to reverse. But a substantial downward readjustment in his numbers—not too precipitous—during the twenty-first century might be the least hazardous of man's adaptive behavior patterns.

Possibility No. 3 might be modified to portray a smooth trend from a maximum height toward which we are now heading, to some level at which the entire world might have enough resources to provide, without severe famine or chaos, a steady state at a level that was both in balance with the earth's ecology and high enough to provide extensive and varied cultural development over most of the globe. This would require the application of a degree of human intelligence, foresight, mutual concern, cooperation and forbearance which has not been in evidence in any previous period of human history.

Any person who feels that these three illustrative graphs of the prospects for the twenty-first century are unduly gloomy is invited to try other assumptions and see where he comes out. It is likely that he will discover it very difficult to find assumptions within the realm of realism which make the prospects look much different from those set forth above.

Concluding comments

It is beyond the scope of this condensed analysis of man's population predicament to propose and describe a set of intelligent responses,

international and national. This is a challenge of enormous magnitude. One phase of it—the question as to whether we have a population problem in the United States, and if so, what should be done about it—was addressed in the February 1970 *Population Bulletin* entitled, "The Population Challenge of the '70s." Other aspects of the problem have been and will continue to be dealt with in the publications of the Population Reference Bureau.

Man's population predicament, to the extent that it is at least partially understood by people who have some concern for the future of their children and of mankind, seems to overwhelm many people into inaction. They feel helpless before a problem of such enormity. The situation is made even more difficult by the fact that the demands of all nations upon their political and social leaders is predominantly for short-range solutions to other critical problems. The population predicament is clearly not something that any national leader can do anything significant about in the short run.

Nevertheless, the enormity and the long-range nature of the problem should not lead to a fatalistic acceptance of its implications. Rather, the fact that population growth has such great momentum and such profound implications for all mankind but for young people especially, is all the more reason for grappling with it immediately and on a worldwide scale.

It is a problem belonging to all nations and may have to be dealt with on a supra-national basis for an extended period if the "Population Crash Curve" is to be avoided in the twenty-first century.

On the individual level, the greater

the number of people who understand the gravity of the problem, the more they talk to one another about it, the more inventive and the more dedicated they become, the greater is the likelihood that we shall be able to change man's age-long reproductive behavior patterns to contribute to his survival rather than his self-destruction.

There is a steadily increasing congruence of interest between the totality of mankind, nations and adult citizens and their offspring in shifting to a pattern of procreation which will, at most, reproduce the current generation. The question is whether the younger generation throughout the world can quickly unlearn the reproductive habits and attitudes of thousands of preceding generations and substitute a new perspective and a new conviction which is strong enough to make a pervasive change in human behavior. It is the younger generation which will decide. Some members of the older generation may have the wit and wisdom to use their influence to help bring about such a change. But the members of the younger generation, if they are provided the essential facts, may well have greater intuitive insight into the nature of "Man's Population Predicament" than most of their parents and teachers. Therein lies the hope of mankind.

Rufus E. Miles, Jr., Editor

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The Grizzly Bear Population

Birth, Life Death

To manage ^{the} grizzly & to understand it we needed to know
size of population, its trend - increasing, decreasing, stable
age structure, sex ratio, reprod. age of females, birth rate
^{longevity} & death rate

In addition this had to be related & correlated with ^{seasonal & daily movements} size
of ranges, social structure and behavior.

How to do this without communication. Solution was
to capture and mark animals - marked known-age
animals.
aging - L.W. of 2 - p. 7

This made counts or censuses reliable & uniform

Drugging techniques, capture in traps - handled over 600
Examples of capture experience - Iran - (L.W. of 2) p. 6

Censuses - no. results

Age structure - p. 7 (L.W. of 2)

Productivity p. 14 3rd edn
av. litter size - 16 ♀ - 40 cubs
av. 2.5.

~~Birth~~
Breeding age - p. 8 (L.W.)
Reprod. rate
Computer modelling

Size of 1959-67 pop.

Man's rel. to bear pop. & to man's pop.

add families

Note: There is considerable, a good bit more that I want to add yet to this chapter, but the general purpose is to give an idea of the population; how it is measured, how it exists, & how it lives. This should include some of the vital info necessary to later computing the overall ecosystem population. In our Trout Creek census, we were not counting all the grizzlies, but only about 75% of them. The next chapter is on mortalities; deaths & I believe I may start it by telling how difficult it is at times to kill a grizzly & give some examples of old frontiersmen and hunters, but also point out how an unsuspecting grizzly, quietly feeding on a carcass, can be dropped with a single bullet. Then I w/bring in the deaths & mortalities of a number of bears

Pop. Chart,

Chased up tree (big crow) #80

Taking teeth & aging

Snuzzles + elk shed together

The Cascade Kilt-recycling

Computer analysis pop figure

Saw almost dying - p 20

Capturing grizzlies - Fodor, Grogman

Productivity as used here (h.27)
is an expression of reproductive
success at the age of 5 to 6
months. (3rd annual report)

See

Abstract - Rep. cycles

Human prof. in
threatening
beast surprise

Compare growth with human / ^{slow grow}

pop. Chart.

Killing of Cubs by
Boars - incident
at dump - manan

General statement on
productivity - low
enemies - few etc.

REPRODUCTIVE CYCLES AND REPRODUCTIVE RATES FOR THE GRIZZLY
BEAR (URSUS ^{L.C.} ARCTOS HORRIBILIS) IN THE YELLOWSTONE ECOSYSTEM

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May 1, 1974

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Abstract

Reproductive Cycles and Reproductive Rates for the Grizzly Bear (*Ursus arctos horribilis*) in the Yellowstone Ecosystem

Precise reproductive rates were calculated for the grizzly bear (*Ursus arctos horribilis*). The length of the reproductive cycle for females in the Yellowstone grizzly bear population was derived from reproductive histories of 30 marked animals. The sample contained 68 reproductive cycles and a combined reproductive period of 231 years. The average reproductive cycle for 30 females was 3.40 years, measured from pregnancy to pregnancy. By varying the sample size, the reproductive cycle varied from 3.21 to 3.40. Minimum breeding age of females was 4.5 years.

The marked females produced a total of 68 litters with an average litter size of 2.24.

replacement rate
Reproductive rate is the number of cubs produced per adult female per year. Reproductive rates for each of the 30 females were calculated by dividing the average litter size by the average length of the reproductive cycle. The average R.R. for the population of 30 marked females was .658. The maximum was 1.500 and the minimum .286.

Average annual litter sizes were determined from annual counts of cub litters. Using these data in conjunction with information on length of the reproductive cycle, we calculated annual reproductive rates for the Yellowstone population for 1959 through 1973. A statistically significant reduction in R.R. occurred from 1970 through 1973. The long-term reproductive rate (15 years) for the Yellowstone grizzly bear population computed from annual counts of females with cub litters and utilizing a reproductive cycle of 3.40 years was .626. This overall reproductive rate of .626

suggests that a population of approximately 180 animals can sustain itself with this low replacement rate only if the mortality rate remains low. Any abnormal or sustained mortality such as excessive control by man or heavy kills by hunters or both should be viewed with concern because this type of mortality could rapidly cause a sharp decline in population size. Population recovery is slow. Extirpation of a small population of grizzly bears can occur quickly and imperceptibly when mortality rates exceed reproduction rates.

Summary

If the federal government is not going to be the major market for the application of federally funded R & D results, then the responsibility for bringing about technology utilization cannot be borne alone by the federal agency funding the R & D. That this problem is now being recognized is shown by the number of bills that were introduced in Congress in 1974, culminating in the Solar Heating and Cooling Act of 1974 (7).

An examination of the incentives for technology utilization in the conceptual framework of TDS (as shown in Fig. 4) reveals the following:

1) Incentives must be applied to each component of the TDS.

2) Different components in the TDS require different incentives.

3) Although information exists concerning a wide variety of incentives that are currently being used by various federal agencies to stimulate technology utilization, most of this information is in the form of raw data compiled by the respective agencies and a substantial effort will be required to collect, compile, and evaluate them.

4) All the components of a TDS must be activated if technology utilization is to occur on a self-sustaining

basis. This makes experimental verification of a particular incentive on a particular component difficult.

5) A federal agency concerned with technology utilization can and should assume the responsibility for identifying all the components of the required TDS, devising incentives for each component and testing them to ensure their effectiveness. Where a TDS does not exist, the federal agency may have to assume the responsibility of creating one. The scope of this effort in many cases may transcend the present authority of the agency, and congressional action may be required to remedy this shortcoming.

References and Notes

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2. There are a number of excellent papers giving accounts of NASA's experiences in fostering civilian applications of NASA-generated technology. For example, see J. P. Kottonstette and J. J. Rusnik, *Res. Manage.* **16**, 24 (July 1973); J. G. Welles, "Contributions to technology and their transfer: a NASA experience," paper presented at the NATO Advanced Study Institute on Technology Transfer, Paris-Evry, France, 24 June to 6 July 1973; M. D. Robbins, *Mission Oriented R & D and the Advancement of Technology: The Impact of NASA Contributions; Final Report* (Univ. of Denver Research Institute, Denver, Colo., May 1972), vols. 1 and 2.
3. Technology transfer is sometimes used to describe information dissemination, but this is only a part of the technology transfer process.
4. These problems have been discussed extensively at two recent meetings: National Symposium on Technology Transfer, sponsored by the Division of Industrial and Engineering Chemistry of the American Chemical Society, held at the Carnegie Institution, Washington, D.C., 13 to 15 June 1972; NATO Advanced Study Institute on Technology Transfer, Paris-Evry, France, 24 June to 6 July 1973.
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6. The Smith-Lever Law, The Agricultural Extended Work Act, 8 May 1914 (Chapter 79, 38 Stat. 372 Title 7, USC, Sections 341-348) authorized universities to use field agents to disseminate the results of agricultural research.
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8. "Agriculture—Environmental and Consumer Protection Appropriations," *Hearings Before a Subcommittee of the Committee on Appropriations*, House of Representatives, 93rd Congress, 2nd Session (Government Printing Office, Washington, D.C., 1974), p. 231.
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11. The Housing and Community Development Act of 1974, PL 93-383.
12. The Geothermal Energy Research, Development, and Demonstration Act of 1974—PL 93-410. It provides a budget of \$50 million for guaranteeing loans for the development of geothermal energy sources.
13. Many innovations have been introduced, disseminated, and applied over the past 100 years without any aid from federal agencies, although the Federal Housing Administration's home loans helped to create a larger potential market in the past few decades for these innovations, and the National Bureau of Standards' activities in testing new building industry products provided an additional incentive to the use of new products.

The Limitation of Human Population: A Natural History

The demographic transition of modern times is a return to a pattern familiar to our hunting ancestors.

Don E. Dumond

In demographic circles it has been commonly asserted that the long-term evolution of man was possible only because his high natural fertility permitted him to overcome the effects of an exceptionally heavy premodern mortality—mortality amounting to a loss before the age of reproduction of

as much as 50 percent of all individuals born (1-3).

A corollary of this same viewpoint is the conclusion that the direction and degree of change in human population size has been governed in preindustrial eras solely by mortality. It is this preconception that has been largely re-

sponsible for "transition theory," which holds that the so-called demographic transition of modern times is the result of a new response toward reduction of growth induced by the rising standards of living and health that have followed upon the industrial and medical revolutions (4).

Recent years have seen attempts to modify these opinions, however, on the part of historical demographers [for example (5-7)], anthropologists [for example (8-12)], and others (13), who base their views upon various data from their respective disciplines. Unfortunately, discussion of the question is hampered on the one hand by the difficulty of constructing adequate demographic arguments from evidence of populations long dead (14, 15), and on the other by the fact that acceptable studies of hunter-gatherers or non-industrial agricultural peoples are limited by the scarcity of such peoples still available for study whose lives have

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not already been drastically changed by the modern world. Nevertheless, my aim in this article is to recapitulate some of this evidence, and to argue from it not only that the recent reduction in population growth in industrial countries is not a new response but that it is the modern equivalent of a pattern of behavior that has characterized most of mankind over the past million years.

Natality and Natural Selection

Biological evolution of any population may be viewed as proceeding by means of an overproduction of young, a portion of which are then forced to die by factors essentially external to the population—predation, parasitism, and the like—or are forced either to emigrate or to die by competition with other population members for scarce resources. The survivors reproduce, and population-wide frequencies of advantageous and disadvantageous characteristics are changed. The most grossly density-dependent factor, over-crowding in relation to resources, leads not only to the outright death of some of the younger individuals who are eliminated in competition, but commonly leads also to a general decline in fertility, apparently as the direct result of a slightly lowered level of nutrition that is otherwise not sufficient to seriously inhibit normal biological functions or behavior. Thus the total size of the population is limited both through reduction in natality and in deaths heaviest in the relatively young, while adult members of the population tend to remain in at least moderate health (7, p. 40; 16).

Both the overproduction of young and the damping of fertility by slightly lowered nutrition provide the potential for a sharp population increase in the event of an increase in resources. It is this that permits rapid expansion of a species to fill a newly opened niche to which it is suited, and it is this that is absolutely necessary to any successful organism, in order to provide for recovery from the occasional nonroutine demographic catastrophies to which all natural populations are potentially subject.

What if a set of expectations based upon the foregoing is translated to the human societies that must be the closest modern equivalents of those of early men? It is true enough that a substan-

tial number of the children in these societies die before the age of reproduction—at least a third of those born, in most cases (17, p. 49)—largely as a result of disease, that is, parasitism. But while natural predation may be present in some situations, it is not a significant check to any known population; and although men fight one another with relative regularity, so that even unorganized and desultory combat might be argued to provide some selective pressure, it seems clear that such fighting has never consistently provided as much pressure as have childhood diseases. One of these elements, then, is uniformly significant, the other only indifferently so; together they may be considered the routine external selective factors.

But a serious reservation must be entered in respect to the density-dependent factor of the lethal intrapopulation competition for resources. In the first place, no examples are at hand of any hunting-gathering people whose population has routinely suffered year-by-year inroads by starvation; rather, their population sizes seem to have been consistently and significantly less than those that could be supported in normal years within the areas in which they reside and by the technologies which they apply. In the second place, the food-sharing propensities of humans and their tendency to imbue close relationships with affective content combine so that when starvation does threaten, it is the entire population, not simply younger and weaker individuals, who experience deterioration. For hunting humans, then, any consistent production of young substantially beyond that necessary to maintain a stationary population must serve in the long run not as a selective advantage, but rather as a serious hazard.

Nevertheless, it can be shown that human populations commonly are fecund enough to permit rapid growth in circumstances of especially favorable resources. Examples are legion: recovery from the effects of epidemics that have resulted in underpopulation, the rapid filling of newly colonized areas, and so on; and it has been suggested that the natural fecundity of human populations is sufficient to permit them to more than double in size in a single generation despite normal mortality (18, 19).

The model that must be adopted for early humanity, therefore, is one in which natality is in approximate bal-

ance with mortality from natural and routine external causes, in which the stable population is of a size well within the normal carrying capacity of the region, and yet in which a margin of fecundity—unrealized fertility—somehow exists as a necessary safety mechanism.

Some Vital Processes among Nomadic Hunters

Indications are that the general state of health among modern hunting-gathering peoples not under close contact with the urban world is relatively good (13, 20). Unfortunately, only in few cases is it possible to obtain adequate data regarding mortality, particularly that in infancy and childhood. One survey of available literature suggests that survival of more than half the population to age 15 is generally to be expected among untouched peoples (17, table 7).

Especially telling is the carefully collected demographic information from a population of !Kung Bushmen of the Dobe area in Botswana. Studies of 165 women, in which their probable ages, their childbirth histories, and the probable ages at death of their parents were determined, led to the conclusion that the expectancy of life at birth was on the order of 32.5 years, with 60 percent of all born surviving to age 15 (21).

Although low by modern health standards, these rates are high enough that had they been accompanied by natality at the level common in many developing nations, there would have been a Dobe !Kung population explosion of remarkable proportions, and for which there is no evidence. Rather, the average completed fertility—that is, the mean number of children born to women who survived to the end of the childbearing period at age 45 to 50 years, was no more than about five even before the increased outside contact of the past few years, a figure just sufficient to produce a stationary or very slowly growing population.

Evidence of similar population balance is available from other recent hunting-gathering societies (8, 22), and additional sources bear witness to a customary low natality among seasonally nomadic hunters (23, 24). Furthermore, there seems to be every indication that the population levels are well below the maximum limit im-

posed by resources routinely available. Indeed, food is plentiful enough that among peoples such as these it has been suggested that social factors are more important in the control of population size and distribution than are resources (22, 25).

These known examples do not serve to contradict the contention that before the modern era the balance between human survival and extinction has been a delicate one; for although mortality may seldom have been astronomical, natality has generally been only sufficient to provide for replacement. Contradiction is provided, however, in the factor that apparently contributes most strongly to that modest natality: the spacing of births, necessary both to accommodate activities normal to hunting-gathering peoples, and to provide for the nutrition of the very young, as will be explained.

The realization of the existence of such a need among hunters was articulated more than 50 years ago in consideration of reports dating about as much earlier (23, 24). In one of its most specific formulations, it is said that the simple inability of a mother to carry more than a single child together with her normal baggage, and her inability to nurse more than one child at a time, impose a minimum limit of 3 years between offspring (8). Other evidence suggests the birth interval among nomadic hunting peoples is more commonly around 4 years (26; compare 27, 28).

One student of the problem has calculated the difference in work that would be assumed by a Dobe !Kung mother under various birth intervals, with the results summarized in Table 1. When one bears in mind that each woman travels an average of 4200 kilometers per year carrying her baggage and young children, the differences in labor expenditure are substantial (29, tables 14.4 and 14.5). Furthermore, the extra labor required for the provision of food for the young does not end when the child begins to walk for himself.

A probably equally compelling need for birth spacing is presented by the relative unavailability to hunting-gathering peoples of foods soft enough to permit weaning of infants at ages under about 2.5 to 3 years (24, p. 127; 29). It should be stressed that this inability to care for more than a single infant at a time is not based simply upon observer's inference, but has been

Table 1. Effect of birth interval on amount of work performed by Dobe !Kung mothers over a 10-year period. [Constructed from Lee's data (29, tables 14.4 and 14.5)]

Work details	Birth interval in years			
	2	3	4	5
Number of offspring after 10-year period	5	4	3	2
Number of years spent transporting two children	8	3	0	0
Number of years spent transporting fewer than two children	2	7	10	10
Average baby weight transported per year (kilogram)	17.0	12.2	9.2	7.8
Average baby weight (kilogram) times average distance traveled (kilometer)	32,064	22,824	17,808	14,256

clearly articulated by the people themselves in case after case (for example, 21, 24, 30).

But given the recognized need for and presence of a relatively long interval between births, the mechanisms that actually effect it are not entirely clear. People of many societies practice postpartum sexual abstinence for a period of significant duration. In a number of cases these periods may in fact last as long as 2 years and more, although the great majority are of 1 year or less (31)—sufficient to result in birth spacing of no more than about 2 years. Although induced abortion has been shown to be well-nigh universal (32), it need not be thought to account consistently for the interval: among the Dobe !Kung, for instance, fetal wastage is reportedly too moderate to indicate a systematic practice of induced abortion (21). One suggestion is that among these last people the lactation of 2.5 to 3.5 years serves to suppress ovulation, although it is admitted that evidence for any clear and complete suppressive effect of ovulation in human populations is most ambiguous (29).

Among some hunting-gathering groups, evidence suggests that the rate of infanticide has been substantial (10, with references therein); in particular, data concerning aboriginal Australians have been said to indicate its practice in between 15 and 50 percent of all births (8, 24). Infanticide was admitted by Dobe !Kung women in cases in which births followed too closely upon one another, although specific instances noted constituted little more than 1 percent of births (21); it was, however, a topic treated with some secrecy, with men apparently suspecting women of practicing it more often than admitted (33, p. 371). Some reports from other !Kung suggest it was probably not uncommon (30, 34).

Whatever the means or combination

of means employed by hunting-gathering peoples to effect the necessary child spacing, the evidence discussed seems to point to a situation very like the model referred to above: The total population of successful hunters is well within the bounds of available resources and remains at a near-stationary level, yet there is a margin of fecundity above the level of surviving births; this margin is held under control by conscious and personally applied mechanisms adopted to effect birth spacing.

If it can be presumed that the mobility- and baby-food-induced limitation upon the natality of relatively modern hunting-gathering peoples also applies to their Pleistocene counterparts, it will allow the projection of some fertility rates reasonable for earlier periods of human development. A series of hypothetical schedules of age-specific fertility rates is provided in Table 2, together with the actual rates for the Dobe !Kung.

Natality and Child Transport

Before I turn to early humans, I shall consider briefly some studies of monkeys and apes, although accurate demographic data collected under completely natural conditions are seldom available. In terms of their mobility, these forms are somewhat similar to human hunters, although moving according to different rhythms.

One study of baboons, based unfortunately on a very small sample, suggests that 40 percent of the offspring survive to the age of reproduction, and that young are born at the annual rate of about 550 per 1000 females of all ages—that is, at least as frequently as every second year for sexually more active females (35). Gestation requires about 6 months, and nursing and transport of the young by the mother occupy

Table 2. Annual age-specific natality rates (per 1000 married women). Schedule 4 is presumed to represent the highest natality feasible for relatively nomadic hunters. For simplicity, figures for births expectable to females over age 44 are here combined with those of age 40 to 44 years.

Age (years)	Hypothetical schedules						Dobe !Kung† (actual figures)
	1*	2	3	4	5	6	
15 to 19	300	250	200	200	150	100	46.5
20 to 24	400	350	350	300	300	250	260.5
25 to 29	500	400	350	300	250	250	205
30 to 34	400	350	300	250	200	200	174
35 to 39	350	250	250	200	150	150	120
40 to 44	250	200	150	150	100	50	64
Average completed fertility among mothers over age 44	11	9	8	7	6	5	4.35

* Schedule 1 is based on data from 20th-century Hutterites, who are among the most fecund people known (58, 67). † Modern !Kung Bushman figures are from Howell (21); their completed fertility before they had contact with Europeans is thought by Howell to have been about 5, so that their precontact natality may be assumed to be roughly approximated by schedule 6.

11 to 15 months (36), when she comes into estrus again and breeds.

Mountain gorillas have been reported to have a birth rate of about 250 per year per 1000 females, with intervals between young varying between 3.5 and 4.5 years. The infant is carried by the mother for about 3 years. About 40 to 50 percent survive to the age of sexual receptivity at 6 or 7 years. The chimpanzee is similar, with birth intervals somewhere between 3 and more than 4.5 years (37, 38).

In all of these cases, which may be taken to represent higher nonhominid primates generally, the mother physically transports her infant during much of the period of nursing; at the end of the period, care of the juvenile by the mother either ends entirely or is substantially reduced. Thus she is not faced with the problem of transporting more than a single infant at a time, and she is not faced with a continuing problem of the provision and preparation of food for her young. Birth spacing is, of course, under involuntary hormonal control (39).

For the early hominids even less information is available. It is thought that even before the advent of the Pleistocene, forms such as *Australopithecus*, now sometimes referred to as *Homo africanus*, had shifted to an omnivorous diet (40), implying a pattern of subsistence and movement closer to that of known hunters and gatherers than to that of ground-dwelling monkeys and apes.

Estimates of age at death of slightly more than 300 *Australopithecus* individuals—a sample within which, unfortunately, infant specimens are almost certainly underrepresented—average 18 to 23 years (37, 41). In one manipulation of the data, McKinley

(37) assumed an age of 11 for sexual maturation, and a period of about 6 years for infant dependency; a comparison of these figures with the data available on survivorship, corrected as nearly as possible to account for missing infant mortality, suggested to McKinley a birth interval of 3 to 5 years, significantly less than the probable period of total infant care (37), but one that would accord with a time of infant transport. The length of the fertile period is, of course, not known. The degree to which natality was under the control of an estrus cycle damped by nursing and child care is also unknown, but in view of some essentially human physical developmental progressions, such as in the teeth (41), it is not farfetched to think that involuntary hormonal control of breeding was giving way at this time.

With the advent of the Middle Pleistocene and the hominids once referred to the genera *Sinanthropus* and *Pithecantropus*, now more often termed *Homo erectus*, the developmental scene is clearer. The substantially modern postcranial skeleton seems to imply a development to maturity not significantly different from that of *H. sapiens*; a similar inference has been drawn from a consideration of the complex matter of cranial suture closure (42, pp. 139–143). Such food refuse as is available, together with instances of the use of fire, suggests strongly that the pattern of subsistence, hence of seasonally nomadic movement and of infant transport, was essentially that of more modern hunting-gathering peoples. It therefore seems probable that the period of fertility and the reproductive system in general was substantially that of *H. sapiens*.

A Natural History of Human

Vital Processes

Ideally, evidence of mortality can be derived directly from skeletal remains. Yet practically speaking, even with large samples there are problems of deciding the extent to which a valid contemporary population is represented (15). Misrepresentation of infant deaths is especially frequent (43), both because of differential survival of bones and because of different disposal measures practiced for corpses of adults or subadults and for those of small children. Valid age and sex determination can also be problems.

Despite these limitations, however, some samples are available that can be used in a tentative way. With the mortality suggested by these, and with some idea of the overall rates of world population growth before the industrial revolution (2, 11), it is possible to estimate the level of natality necessary to provide at least minimally for such an increase.

A recent study by Acsadi and Nem-eskeri (42) has focused in particular upon the history and prehistory of mortality, and offers the unusual advantages that comparable and systematic methods of age determination were used in assessing most of the populations, and that relatively detailed life tables were generated from the data.

Based on the life tables, some relevant survivorship schedules are plotted as curves in Fig. 1. Curve A is based ultimately upon fragments of 22 individuals of *H. erectus*, of the subspecies formerly assigned to the genus *Sinanthropus*, which were recovered in excavations at the Chinese cave of Choukoutien, and probably date from the Middle Pleistocene (44).

Curve B is based on the remains of more than 200 individuals recovered from the caves of Taforalt and Afalou in the Maghreb region of Morocco and Algeria, dating from the end of the Paleolithic or the beginning of the Mesolithic, at the end of the Pleistocene (45). It would almost certainly be a mistake to assume this schedule to represent a typical nomadic hunting population, however, for the sample derives from the very period in which increased sedentation is demonstrated in the archeological record. Indeed, the systematic disposal of dead in a single location must of itself indicate a measure of residence stability, so that any cemetery must be suspected either of deriving from relatively sedentary folk

or of providing only a haphazard mortality sample. The caution must apply also to the remains from Choukoutien, as well as to those from certain other series that are not dealt with directly here (46). This problem of sampling the mortality of prehistoric hunters will be returned to.

Curves C and D are derived from the highest and lowest of the age-specific mortality rates from substantial series of skeletons of European agricultural peoples (47). A number of other rates (42, 43) were eliminated from consideration here, simply because the collections on which they were based included no figures for deaths in early childhood. Indeed, even curve D may be suspect in that regard (48). In all curves, pooled data for both sexes is used, both for consistency, since separate information for the sexes is not available in all cases, and because it seems safer in view of the difficulty of accurately sexing immature skeletons and of the apparent tendency to wrongly identify the sex of even a proportion of older ones (17).

Table 3 presents estimates of the net reproductive rate (that is, the proportion of itself that one generation of females will produce) within a stable population in which the females conform to the mortality curves of Fig. 1, and to the natality rates of the separate hypothetical schedules of Table 2. For simplicity, an equal sex ratio is assumed. In succeeding sections I will trace the history of vital processes through several stages of human culture.

Early Hunters

The world population of 10,000 years ago—the end of the Pleistocene and the practical beginning of the era of more sedentary human living patterns—has been estimated at from about 3 to 5 million, the culmination of a long-term rate of increase averaging from 0.0007 to 0.0015 percent per year, and spanning 1 to 2 million years (2, 28). In the present discussion, a rate of increase sufficient to achieve this long-term result is taken to be represented by any net reproductive rate over 1.0.

Table 3 indicates that a population with a stable mortality of type A (Sinanthropus) and a stable natality such as that of the rates in schedule 4 (the highest probably feasible for hunting-gathering peoples if the assump-

Table 3. Net reproductive rates calculated from natality shown in Table 2 and mortality shown in Fig. 1. It is assumed that sex ratios are equal and that all women are always married.

Mortality (Fig. 1)	Natality schedules (Table 2)						Dobe !Kung
	1	2	3	4	5	6	
A (Sinanthropus)	1.05	0.87	0.78	0.69	0.58	0.50	0.43
B (Maghreb type)	1.89	1.56	1.39	1.21	1.02	0.88	0.76
C (Agriculturalists)	2.25	1.86	1.65	1.45	1.21	1.05	0.91
D (Agriculturalists)	2.81	2.70	2.41	2.11	1.75	1.52	1.31

tions regarding child spacing are correct) would replace only about two-thirds of its female population each generation. A population with such mortality among females could replace itself fully only with fertility approaching that of schedule 1, which is based on modern figures that are the highest ever recorded for a group of humans. It is therefore possible to conclude that the small Choukoutien skeletal collection almost certainly does not constitute a valid sample of *H. erectus* mortality (49).

On the other hand, a population with mortality of type B (Maghreb) could maintain itself with a fertility similar to that of schedule 5. And a population with mortality similar to that of Dobe !Kung, which falls between C and D, much closer to the latter, would experience with the same natality a significant population increase, an increase which surely could not have been accommodated for any substantial period of time under stable hunting-gathering conditions.

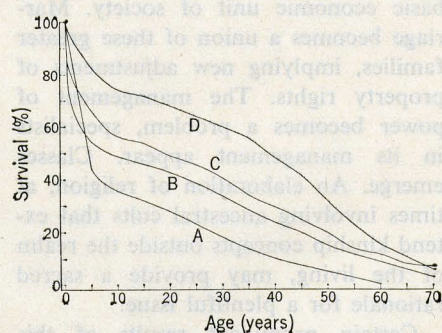


Fig. 1. Survivorship derived from skeletal evidence, both sexes, constructed from the data of Acsadi and Nemeskeri (42). (A) Sinanthropus (42, table 49); life expectancy at birth, 13 years. (B) Maghreb type derived from remains of late Paleolithic or early Mesolithic populations at Taforalt and Afalou (42, table 104); life expectancy at birth, 21 years. (C) Agriculturalists, composite data from 1st- to 4th-century Roman era population and 9th-century Frankish population (42, tables 121, 127); life expectancy at birth, 25 years. (D) Agriculturalists of the late Roman era (42, table 124); life expectancy at birth, 35 years.

What seems to be a weakness of the model developed here is that it presumes substantially all of the females of the population to be married at a very young age. However, it is clear from the anthropological literature that in nomadic hunting-gathering societies virtually all nubile females are married (with nubility frequently arriving before puberty), creating thereby the most important economic unit as well as the reproductive one.

Through the recognition of real kinship bonds, or through various more or less fictive kinlike ties, any such nuclear family is then presented a wide choice among other families with whom legitimately to affiliate and draw assistance in the face of fluctuating resources; despite any number of these affiliations, however, it remains a relatively autonomous unit (24, 50). Put another way, responsibility for the day-to-day business of maintaining life falls squarely upon the small family, parents and their children, hence the repercussions of overprocreation are felt immediately and inescapably by the procreators themselves; each couple is responsible for its own progeny.

As noted earlier, it has been suggested with some empirical support that humans have commonly been fecund enough that, when presented with unoccupied, favorable territory, they have been capable of doubling their population in a single generation—that is, of achieving a net reproductive rate of 2.0. From Table 3 it is evident that populations with mortality no heavier than that of type C, normally balanced by fertility equivalent to that of type 6, could without shortening birth intervals below about 3 years succeed in achieving a population growth at the rate of 50 percent per generation, if their natality were allowed to increase to that of schedule 4. As mentioned, this level is probably the highest ordinarily feasible for nomadic hunters (51). Furthermore, if either mortality or the need for mobility were temporarily lessened for such people by an entry into new, rich

surroundings, even more rapid growth (whether at the rate of 2.0 is not so certain) would be possible.

In short, an early hunting population with mortality no more stringent than that of type C might be expected to maintain itself and to possess at least a modest margin of unrealized fecundity, even if the need for child spacing is taken into account. In view of the data on the !Kung Bushmen, survivorship among most early hunters may have been substantially better than that of type C, providing an even greater margin of fecundity to be held in check by simple, consciously applied controls.

It is unfortunate and somewhat embarrassing that we have no convincingly complete sample of the mortality of any fossil population of hunter-gatherers. It would be foolish to argue that mortality as low as that of the single example of the Dobe !Kung was consistent either among modern hunters or their Pleistocene forebears. On the other hand, if the requirement for mobility and the resultant reduction in natality have been consistent and real, the relationships between natality and mortality that are summarized in Table 3 seem to hint that mortality was effectively no higher under conditions of hunting than under those of a more sedentary life, including agriculture. Indeed, a probable increase in the level of parasitism in sedentary agricultural societies (to be mentioned shortly) may mean that the mortality rates of hunters were more often significantly lower.

Preindustrial Agriculturalists

It has been estimated that between about 8000 B.C. and A.D. 1750 the population of the world increased some 160 times, to around 800 million. To do this it doubled itself less often than once each 1000 years, achieving an average yearly growth rate of less than 0.1 percent (2). Approximately this rate has been estimated for the Near East during the Neolithic (52); it is less than the rate of growth that is indicated in major countries after the beginning of the Christian era, which may over the long run have amounted to between 0.15 and 0.4 percent per year (12, 19). Although these overall rates of growth are small when compared with some of those to be encountered in the modern world, they are drastically above that of the Pleistocene.

Several arguments have recently been made to the effect that sedentism itself is sufficient to promote population growth, simply by relaxing the need for movement and child transport (27, 29, 53). Certainly it is with the Mesolithic era that the growth of settled villages can be generally observed. Then and later, efficient strategies of collecting seeds or coastal products are known to have been successfully employed by people with relatively high population densities. In some places what have been claimed to be true urban population agglomerations may even have been supported in this way (54); yet in most favorable locations agriculture apparently followed shortly after the development of intensive collecting economies such as those that characterized the Mesolithic.

Whether one adopts a populationist notion of the causes of agricultural development (33, 55), or a more traditional or "neo-Malthusian" approach in which innovation in agriculture is conceived as bringing on population increase (28, 56), or one that is somewhere between the two (19, 53), there seems to be no argument against the proposition that overall population growth and agriculture as a way of life have gone hand in hand. And with them have come increasingly ramified and exclusive family systems, possessed of increasingly complicated property arrangements and inheritance practices. These larger kin groups take over control from the nuclear family as the basic economic unit of society. Marriage becomes a union of these greater families, implying new adjustments of property rights. The management of power becomes a problem, specialists in its management appear. Classes emerge. An elaboration of religion, at times involving ancestral cults that extend kinship concepts outside the realm of the living, may provide a sacred rationale for a plentiful issue.

Certain prominent results of this changed way of life would seem to militate against population increase. In most agricultural societies there are a significant number of individuals of both sexes who never marry. The degree to which this is the case varies greatly from society to society, and no attempt at exhaustive review need be made. But, as an extreme example, the common Medieval European practice of impartible inheritance of land tended to accompany the development of the so-called "stem" family, in

which only the heir to the property achieved sanction to marry and reproduce, while younger siblings remained unattached and unpropagating; in some cases fully half the nubile females were reportedly so removed from reproduction. Where lands have been divided among siblings, on the other hand, marriage has been less restricted, with fewer than one-fifth, and sometimes almost none, of the females remaining unmarried (7, 18, 24, 57). When marriages and attendant property settlements are negotiated by families there also frequently has resulted delay in marriage for those who do achieve it—this being a condition that will lower overall natality, of course, inasmuch as the total number of children produced is in approximately linear relationship to the age of females at marriage, when that age is between 20 and 35 (58).

Nevertheless, it is almost a truism that agricultural endeavor has commonly tended to encourage high natality, because additional offspring are thought to be economic benefits (24, 59). Some students suggest that this tendency may be further increased where there are certain kinds of taxes levied by central governments—colonial or otherwise—making the perceived economic advantage of another offspring sufficiently attractive that it outweighs even a noticeable resultant depression of family living (59, 60). Furthermore, the existence of the more complex and economically dominant extended family, often reflected in an expanded, supranuclear family residence unit, tends to remove parents from direct responsibility for both the economic and the affective support of their own progeny, hence from direct and immediate experience of consequences of any excess in procreation. Whatever the factors most at work in specific cases, among married women the rate of natality increases, so that the average interval between births in preindustrial agricultural societies often approaches, if it seldom quite achieves, the low figure of 2 years (7, 58, 61).

Mortality is often suggested to have declined somewhat with the beginnings of agriculture, with the decline responsible for much of the estimated increase in the rate of overall population growth (2, 3, 42); such a suggestion has nevertheless been questioned by others (12). And although the survival curves of Fig. 1 may seem to support it, the evidence for a decline in mortality is in fact sketchy, simply because

valid evidence of mortality among hunting-gathering peoples is so difficult to come by. The level of disease must have increased with sedentary living and the accompanying crowding of population, and disease-caused mortality, at least, must have risen significantly. In preindustrial cities it was apparently especially high (62). For present purposes it seems more acceptable to conclude that mortality remained at least as heavy as it had been during earlier less sedentary millennia.

Meanwhile, any increase in natality, perhaps up to as high as schedule 3 in the long run, could provide for substantial population growth even though the age at marriage was raised, and even though a significant portion of females might be withdrawn from reproduction through failure to wed.

Despite the probability that agriculture as a way of life tends to promote the production of children as economic assets, it cannot be really surprising to find it shown by historical demographers that many populations of this sort purposefully limited their production of children before they ever felt the effects of the revolution in medical technology (6, 7). They must have done so, for in spite of the inhibiting social factors mentioned earlier, population increase throughout the era of preindustrial agriculture would otherwise certainly have exceeded the relatively modest overall rate it in fact achieved.

After the Revolutions

The situation occasioned by the industrial and medical revolutions is familiar to all of us, and will be touched upon only lightly. In those countries participating directly in the industrial revolution, a sudden burgeoning of population was responded to by a drastic drop in natality, in what has been called the "demographic transition." The original view, that the population increase had been brought on by a sharp decline in mortality, seems to be modified now by knowledge that the actual population rise was triggered by an increase in fertility shortly before or contemporaneously with the advent of the industrial revolution, and significantly before any real decline of mortality through medical advances (4, 7; compare 63). Even as mortality was being drastically reduced by the medical extensions of the new technology, a marked down-

turn in natality occurred, the result of individual choices exercised regarding marriage and childbirth, the latter assisted by technological applications. Sociological explanations of the fertility decline include the point that the major functions of the old extended family were shifted to other specialized institutions, and that the decrease in mortality called for the production of fewer total offspring in order to provide a desired level of issue (4).

While this may be true, I prefer to place emphasis on the return to primary importance of the nuclear family, with a renewal of its former status as the basic economic, affective, and residence unit (64). Except for the absence of any immediate need for the modern human mother to transport her offspring several thousand kilometers per year on her back or her hip, the position of the nuclear family within industrial society is remarkably similar to its position in societies of nomadic hunters and gatherers: as an autonomous unit it assumes direct responsibility for its own progeny.

Given the success with which human hunting populations regulated themselves for so long and in such nice balance with available resources, it should not be at all surprising on the one hand that the relatively high fertility of agricultural society was capable of being reduced substantially and rapidly to cope with the new needs of industrialization, and on the other that Western prosperity in the mid-20th century was often accompanied by a marked rise in natality.

The recent general rise in population in the industrially undeveloped countries is a rise that *has* clearly been brought about by extensions of the revolution in medical technology and has not been accompanied by a redefinition of economy and social life around the independent nuclear family. The presumed advantages of offspring to agricultural peoples have continued within the general perception, and total numbers have swelled sharply with the new and improved level of survivorship. Increased communication and cooperation between modern and increasingly compassionate nation states have even, by leading to massive programs of international assistance and relief, decreased the punitive effect on individual procreators of their own steadily declining resources. Even should old, tried measures of abortion, infanticide, and the like be resorted to, the limits of their efficacy have been

overshot. Where these measures may have been adequate for a population faced with a normal mortality of a third of all offspring in the first 15 years of life, they are not adequate at all for populations faced with child mortality a fifth of that. Furthermore, the imposition of official value systems of Western industrial nations have often caused the use of some of these older and once-practical measures of population limitation to be held criminal or at least thoroughly unacceptable.

This is the dilemma that is so often decried in articles like this one, where a resolution is both groped for and argued.

Summary and Conclusions

In this article I have suggested that overproduction of offspring by early human populations would have tended to work to the selective disadvantage of the entire society, but that, nevertheless, a permanently successful society requires some margin of unrealized fecundity with which to respond to any catastrophic decreases in size. If this is true, without involuntary hormonal control of breeding and in the absence of a clearly effective damping of ovulation by lengthy lactation, it must also be true that people of successful societies have always limited their natality below the level of their reasonably achievable fecundity.

Among early hunters, the strongest motive for keeping this margin of possible births unrealized apparently lay in the need experienced within each nuclear family to space births in order to permit the mother to perform the tasks expected of her. This motive probably existed throughout the Pleistocene, and would have resulted in relatively consistent efforts by individuals to space their offspring.

With the advent of sedentary life, this motive for child spacing was considerably weakened. Residence in extended families tended to remove parents from direct economic and affective responsibility for their own issue. Among agriculturalists, in particular, children have generally been considered an economic advantage, and this has encouraged some increase in fertility rates, although natality has at the same time been inhibited by a rise in age and a reduction of the proportion of the women who married. Under conditions of centralized rule, social stratification, and colonialism, demands

of rulers for taxes and rents may often have served to promote a further labor intensification and population increase. But seldom, if ever, has natality approached the maximum possible.

In these preindustrial cases, the rate of natural mortality was sufficiently high to have made the margin between tolerable and intolerable births relatively small, so that the number of births to be aborted or offspring to be disposed of by any single female were relatively few, whatever her motivation. Although it may be technically correct to say that mortality served as the chief controlling factor of population dynamics—simply because natural deaths before or during the period of reproduction took away a far greater proportion of the population than was prevented or removed by conscious population limitation measures—it seems more meaningful to argue that the significant margin of control lay in voluntary measures.

Furthermore, and despite some arguments to the contrary, the evidence provides no clear support for any general decline in human mortality before the industrial and medical revolutions. I suggest rather that there was no consistent decline until around A.D. 1900; that earlier population fluctuations were the result of fluctuations in natality at least as often as they were of short-run variations in mortality; and that a regular component in the natality rates was voluntary intent. Thus it is unreasonable to argue as has been done that human beings, alone among living organisms, have failed to develop any density-dependent mechanisms of population control (65). Rather, their primary density-dependent mechanism is the most flexible there is, the only device flexible enough to suit the needs of the enormous variety of societies of humans, and a device that is consequently subject to considerable short-run aberration—that is, self-consciousness and volition.

Decisions regarding population limitation have been highly personal ones made by individuals not so much upon the basis of broader long-range subsistence questions or of community policy as upon considerations regarding the amount of short-run effort they are able and willing to invest in each child. It is no doubt fair to say that there have always been families larger than average, willingly produced by parents who accept the added burden. In the modern industrial world, despite the evident current fad for zero popu-

lation growth as an abstract ideal, the most cogent consideration will undoubtedly continue to be whether the production of another offspring is worth the investment of time and money for the care and education that is now demanded for full social membership. Thus the position of the potential parent is directly analogous to that of the adult in a hunting-gathering society, in which the question is whether the child is worth the extra labor in transport and the preparation of food, or the risk of depriving a sibling of milk. In both, the cost of children to parents is high. And in either case the decision is a personal one that may be expected to vary somewhat between individuals, regardless of the similarity of their particular histories or of their cultural surroundings.

Although a similar choice is made in modern agricultural societies and in developing countries, the limits of the decisions are different simply because the cost of children to their immediate parents is still low: portability is not a factor, neither is education, and the general decline in living is spread among everyone. The choice may be expected to change significantly only as the direct cost to each parent of each child—in effort, in money, or in anguish—rises.

This is an argument that a change in values and social organization is the key to a change in the present upward population trend, but it is by no means an argument that improved birth control technology is not similarly important (66). For modern mortality-reducing measures have vastly increased the numbers of family limitation decisions that must be made; to assist in this, improved technology is indispensable.

There has been a tendency for demographers to assume that all preindustrial peoples have possessed values similar to those of modern, predominantly agricultural, underdeveloped nations, with high fertility and high mortality. I have tried here to argue briefly that this has not been the case, that, indeed, the outlook of humans for most of their career as a species has been rather different, and that their behavior in industrial nations has been more like a return to that of our earlier evolutionary history, than a uniquely new development.

In most cases where growth of population has occurred, it has been both recognized and tolerated. The

modern growth of population will be slowed permanently only to the extent that in the judgment of each individual, whatever his background, extra children are worth less than they will cost in time, in effort, in money, in emotion—or in the threat that is posed by their very existence.

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Graduate Admission Variables and Future Success

We cannot tell whether the standard selection measures used by graduate schools are valid.

Robyn M. Dawes

The standard variables considered in selecting students for graduate school do not correlate well with later measures of the success or attainments of the selected students (1, 2). The low correlations have led at least one investigator (3) to propose abandoning one of these standard variables, the Graduate Record Examination (GRE). The purpose of the present report is to demonstrate that variables that are the basis for admitting students to graduate school *must* have low correlations with future measures of the success of these students.

The usual reason given for such low correlations is that the admitted students tend to have scores within a restricted (high) range on each of these variables and that empirical investigations are necessarily limited to these students, the rejected ones being typically unavailable to the researcher. *Potential* correlations based on the whole applicant group might be much higher, but there is no way of evaluating such correlations empirically, and "prophecy" formulas for estimating them are of dubious value because the restriction is so severe and because the covariance

structure of the variables for the selected group is different from that of the applicant group. With the ratio of applicants to selected students increasing every year (it was 14 to 1 for the class entering the psychology department of the University of Oregon in the fall of 1974), the problem of restricted range likewise becomes worse. But, as will be demonstrated later in this article, that is not the main problem.

The main problem concerns the covariance structure of the admissions variables in the selected group. That structure consists largely of negative correlations because "whatever vague methods are used by admissions committees for combining criteria, these methods tend to be compensatory" (1). Even if a multiple elimination procedure is used to screen out unacceptable applicants at an initial selection phase, choice from among those passing the screening tends to be compensatory. Thus, if selected applicants are low on any particular variable, they will be high on others. It follows that for any two variables important in selection there will be people who are high-high, high-low, and low-high, but few

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or none who are low-low; negative correlations are a likely result. Pairs of variables on which there are many selected applicants in the low-low quadrant will consist only of those variables that the admissions committee considers to be relatively unimportant to selection—that is, not predictive of later success.

As has been pointed out by others (4), negative correlations between predictor variables can result in large multiple correlations even when the predictor variables considered singly have only moderate validity. This article makes the converse point. Knowledge of the covariance structure together with assumptions about possible values of the multiple correlation yields information about the potential validity of the predictors. Specifically, it is assumed that given the vagaries of gradu-

ate education and professional development it would not be possible to predict meaningful later measures of success or attainment with a high degree of precision from a combination of the variables used in selecting students for graduate school. It follows (as will be demonstrated algebraically below) that when these predictors themselves are negatively correlated their single validities must be low. The point will be illustrated with two variables—undergraduate grade point average (GPA) and GRE aptitude score (the total scaled score on both the verbal and the quantitative tests).

Figure 1 presents data showing that these compensate for each other in selection and therefore tend to be negatively correlated among the selected students. The figure shows scaled GRE scores plotted against GPA for each of

the last six entering graduate classes in the psychology department at the University of Oregon (N 's vary from 9 to 22). The correlations are all negative, ranging from $-.04$ (not statistically significant) to $-.54$ ($P < .01$). The years for which the correlations are most negative are those in which a number of "late bloomers" with master's degrees were admitted; several of these students had strikingly low undergraduate GPA's but high GRE's and demonstrated ability to do graduate work. (Incidentally, the correlations between GPA's and GRE's for the *applicants* to these entering classes are all positive; for example, $r = +.19$ for 1973, $+.18$ for 1969.)

Now consider the degree to which a linear combination of GPA and GRE can predict some future variable of interest (such as measure of success or attainment). The R^2 for the prediction is

$$R^2 = \frac{r_1^2 + r_2^2 - 2r_1r_2r}{1 - r^2} \quad (1)$$

where r_1 = correlation of GPA with the variable, r_2 = correlation of GRE with the variable, and r = correlation between GPA and GRE. This equation may be found in a number of elementary texts (5). Multiplying both sides by $1 - r^2$ yields

$$(1 - r^2)R^2 = r_1^2 + r_2^2 - 2r_1r_2r \quad (2)$$

Rearranging terms yields

$$1 = \frac{(r_1 + r_2)^2}{R^2[2(1 + r)]} + \frac{(r_1 - r_2)^2}{R^2[2(1 - r)]} \quad (3)$$

which defines an ellipse in the two variables ($r_1 + r_2$) and ($r_1 - r_2$), as illustrated in Fig. 2.

Now consider a potential study conducted on the selected students for the academic year 1974–75. (This year is chosen because it illustrates the problem most dramatically.) Given the vicissitudes of graduate study (the personal, professional, and random components of professional development are probably well known to the reader), surely no linear combination of GPA and GRE is going to account for more than 50 percent of the variance in any meaningful measure of future success, attainment, or self-actualization. (Readers with a less Ecclesiastes-like view of life than that of the author may substitute their own values in what follows—as may those who believe that professional development is even less predictable from entrance characteristics,

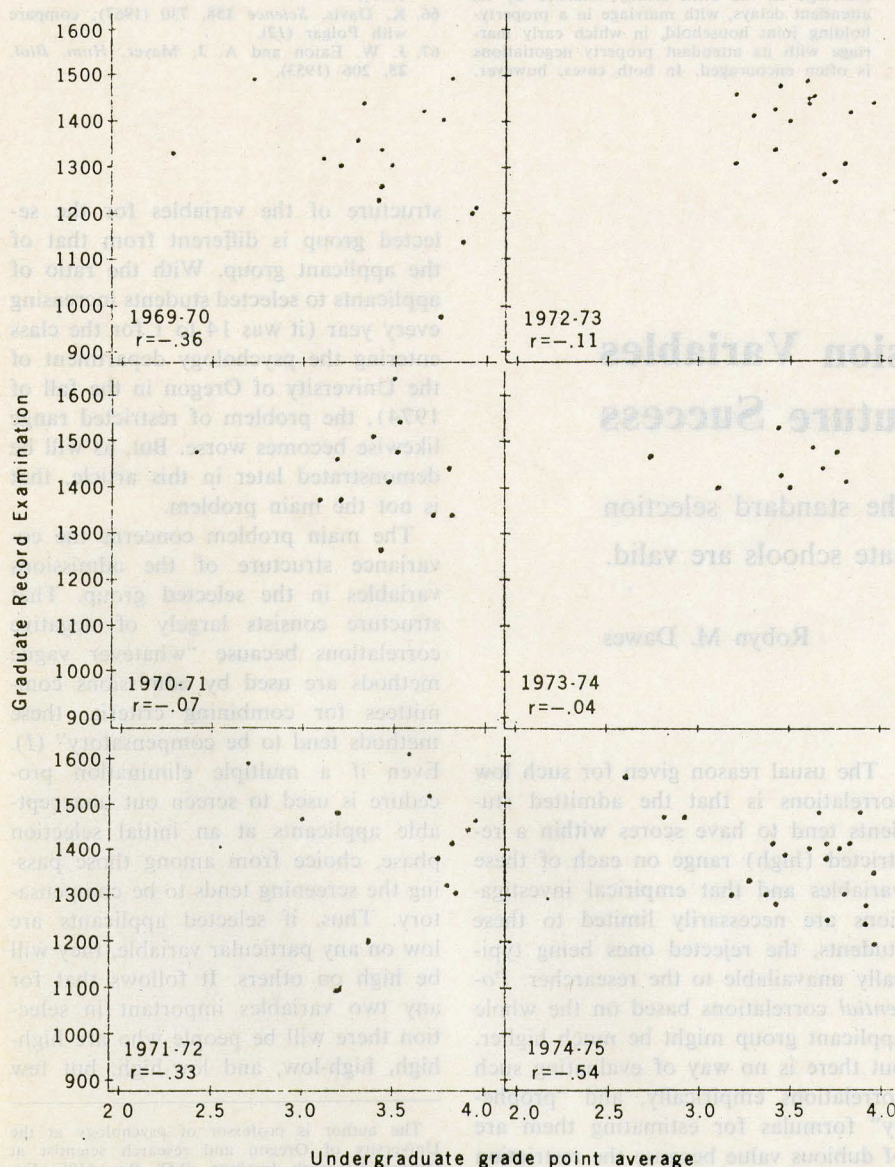


Fig. 1. Scatter plots for classes of graduate students in psychology, University of Oregon.

The trapping, marking, tatooing, instrumenting and tracking by radio were all techniques employed to gather information on the population of grizzlies. This also includes such techniques as the removal of the fourth pre-molar for aging or the making of plaster casts of the feet and jaws. When a ~~xxxxxxxxxxxxxxxxxxxx~~ sufficient amount of data was recorded, it was tabulated and tentatively analyzed. Each year we were obtaining a better understanding of the grizzly bear population. Our census of the bear population was a sample of the entire ecosystem population and as pointed out earlier consisted of a 77% sample. The information obtained from this sample would be applicable to the entire population of bears, even though some individuals making up this total, we had never observed or handled. In 1968, after 9 years of data gathering, we were able to work out with some degree of certainty the population parameters that we had set as one goal of our study.